Dissertation on

THE STUDY OF THE ORIGIN, COURSE, DISTRIBUTION AND BRANCHING PATTERN OF THE INFERIOR EPIGASTRIC ARTERY

Submitted in partial fulfillment for

M.S.DEGREE EXAMINATION
BRANCH – V ANATOMY

Upgraded Institute of Anatomy
Madras Medical College & Research Institute,
Chennai – 600 003

THE TAMILNADU Dr.M.G.R. MEDICAL UNIVERSITY
CHENNAI – 600 003
TAMIL NADU

MARCH 2009

CERTIFICATE

This is to certify that the dissertation work on **THE STUDY OF THE ORIGIN, COURSE, DISTRIBUTION AND BRANCHING PATTERN OF THE INFERIOR EPIGASTRIC ARTERY** is the bonafide work done by **Dr.V.ANANDHI** in the Institute of Anatomy, Madras Medical College, Chennai – 600 003 during the year 2006 – 2009 under my supervision and guidance in partial fulfillment of the regulation laid down by **The Tamil Nadu Dr.M.G.R Medical University**, for the M.S., Anatomy branch V examination to be held in March 2009.

Dr.T.P.Kalaniti M.D.,
Dean
Madras Medical College,
Chennai – 600 003

Date:
Station:

Dr.Christilda Felicia Jebakani M.S.,
Director
Institute of Anatomy,
Madras Medical College
Chennai 600 003

Date:
Station:

ACKNOWLEDGEMENT

I wish to express my exquisite thankfulness and gratitude to my most respected teacher and guide **Dr.Christilda Felicia Jebakani M.S.,** Director and Professor, Institute of Anatomy, Madras Medical College, Chennai – 3, for her invaluable guidance, persistent support and quest for perfection which has made this dissertation take its present shape.

I'm thankful to **Dr.T.P.Kalaniti M.D.,** Dean, Madras Medical College, Chennai -3 for permitting me to avail the facilities in this college for performing this study.

My heartfelt thanks to **Dr.I.Jeyaraj, Dr.B.Chezhian, Tmt.M.S.Thenmozhi, Dr.V.Lokanayaki, Dr.V.Sathialakshmi, Dr.M.Vijayalakshmi and Dr.P.Murugesan**, Assistant Professors, Institute of Anatomy, Madras Medical College, Chennai – 3, for their valuable suggestions and encouragement throughout the study.

My gratefulness to **Dr.D.S.Swaminathan M.D.R.D.,** Director, Barnard Institute of Radiology, Govt. General Hospital, Chennai – 3 and **Dr.Sundaresan** for their help in the radiological study.

I sincerely thank **Dr.K.Saraswathi M.D.,D.G.O.,** Director, Institute of Obstetrics & Gynaecology, Chennai for helping in the foetal study.

I earnestly thank my seniors, **Dr.C.Jayanthi Gnanadeepam, Dr.M.Jeyanthi, Dr.Preethi Ramya, and Dr.V.Anitha** and my **helpful**

juniors and other members of faculty who have been supportive and encouraging throughout the study.

I would be failing in my duty if I do not thank my colleagues **Dr.K.Rajeswari, Dr.R.Sudha** and **Dr.N.Mugunthan** for their constant encouragement and unstinted co-operation.

I’m thankful to the **technicians** and all other staff members for helping me in carrying out the study.

I’m grateful to my **husband, sister, mother-in-law, parents and children** who have helped making this study a reality.

Above all, I thank the **ALMIGHTY GOD** who has showered his choicest blessings on me and guided me in every step of the dissertation.

CONTENTS

INTRODUCTION

Variations are rampant in nature. Although many of the variations cause no disturbance in the functions of the body, they may be of great importance to the surgeons.

Developmental variations of nerves, blood vessels, lymphatics, bones, joints, organs and almost all tissues in the body occur.

Interesting variations and anomalies in the origin and course of arteries have long received the attention of anatomists and surgeons.

The inferior epigastric artery or the deep inferior epigastric artery as it is usually referred to by surgeons, is found bilaterally in the anterior abdominal wall. It arises from the external iliac artery in the extraperitoneal connective tissue just posterior to the inguinal ligament. It then ascends obliquely along the medial margin of the deep inguinal ring. Then it pierces the transversalis fascia and ascends in front of the arcuate line and continues upward between the rectus abdominis muscle and the posterior lamina of its sheath. It divides into numerous branches which anastomose with those of the superior epigastric artery (Fig.1).

The branches of the inferior epigastric artery are cremasteric, pubic, muscular, cutaneous, peritoneal and anastomotic.

Of particular importance is the pubic branch which shows a great degree of variation and may become an abnormal obturator artery. This pubic branch anastomoses with the pubic branch of the obturator artery. This connection has

been referred to as the corona mortis (crown of death).There is danger of laceration of the crown of death when blind dissection is done along the iliopectineal line.

The presence of the variant vessels in the retropubic region can become a matter of great concern to orthopaedic surgeons, urologists, gynaecologists and general surgeons, who perform surgical procedures in this area.

Variations are also seen in the origin, branching pattern, and pattern of anastomoses of the inferior epigastric artery.

During the last 15 years laparoscopic surgery has evolved from a rarely performed surgical venture to a daily occurrence. The inferior epigastric artery is at risk of injury in laparoscopic surgeries during trocar insertion into the anterior abdominal wall where the inferior epigastric artery and its branches lie.

Hence the study of the vascular anatomy of the inferior epigastric artery gains much importance.

A man can no more do good surgery without

anatomical knowledge than a pilot can safely

guide his boat without knowing the channel.

- John Chalmers Dacosta

AIM OF THE STUDY

Since the dawn of Plastic surgery, the lower abdominal region has always been a loyal provider of abundant well-perfused tissue. After being first used in pedicled and tubed flaps for distant transfers, the lower abdomen skin and fat was discovered to be an ideal material for breast reconstruction. The specific use of the rectus abdominis musculocutaneous flap was pioneered by Drever in 1977 and a few years later Hartrampf showed that the skin island could be harvested transversely across the lower abdomen. The transverse rectus abdominis muscle (TRAM) flap was born and it eventually became the gold standard in autogenous breast reconstruction (Fig.2). The free TRAM flap demonstrated better vascularity over its pedicled counterpart due to the vigorous blood supply brought in by the deep inferior epigastric system.

The TRAM flaps are also used to cover large defects of the groin with extensive wounds of the groin resulting from trauma or ablation of carcinoma.

Laparoscopy has become an established diagnostic and therapeutic modality in gynaecology, general surgery and urology. Many of these innovative techniques require the insertion of large trocars through the anterior abdominal wall. Because of the rich vascular supply of the anterior abdominal wall, the incidence of abdominal wall vessel (inferior & superior epigastric artery) injury is increased by these techniques (Fig.3). Delayed recognition of inferior epigastric artery injury can lead to profound hypotension and morbidity. A thorough understanding of the anterior abdominal wall vascular anatomy will minimize the risk of inferior epigastric artery injury during laparoscopy.

In the operations for relief of femoral hernia, the pubic branch of inferior epigastric artery is at risk of injury.

Anastomoses between the pubic rami of inferior epigastric artery and the obturator artery has been referred to as the corona mortis (crown of death). In many procedures of the retropubic region, attention needs to be paid to the corona mortis, to avoid catastrophic bleeding.

Pseudoaneurysm of the inferior epigastric artery following abdominal wall suturing has been reported, particularly when abdominal wall retention sutures are placed.

The inferior epigastric artery is suggested to be a good conduit for coronary artery bypass grafting (CABG) because of the low susceptibility to thickening of its intima, low risk of ischaemic necrosis and good flow compliance.

The internal mammary artery arising from the subclavian artery, gives off the superior epigastric artery which communicates with inferior epigastric artery.

This provides an important collateral network in aorto-iliac occlusive disease.

For the correction of erectile dysfunction microvascular anastomosis is done between the inferior epigastric artery and the deep dorsal vein of penis.

The inferior epigastric artery is used as an interpositional vascular graft in liver transplantation cases with postoperative hepatic artery obstruction to restore the arterial inflow to the transplanted liver.

The versatility of the inferior epigastric artery as a vascular graft in various areas and the recognition of its growing importance in the retropubic region and anterior abdominal wall have all prompted me to study the inferior epigastric artery in detail under the following parameters.

I. Origin of the inferior epigastric artery

a) From the external iliac artery or from any other source of origin.

b) Site of origin from the external iliac artery in relation to the inguinal ligament.

II. Level of entry into the rectus muscle ; upper, middle, or lower third (Fig.4)

III. Single or double stem of inferior epigastric artery before entering the rectus muscle substance.

IV. Branches of the inferior epigastric artery.

V. Presence of abnormal obturator artery and its course in relation to the femoral ring.

VI. Pattern of anastomoses of the inferior epigastric artery with the superior epigastric artery.

VII. Level of anastomosis with the superior epigastric artery; at or above the level of umbilicus.

VIII. Distance of the inferior epigastric artery from the important landmarks of the abdomen and pelvis (Fig.5).

a) Distance of the inferior epigastric artery from the midline at the level of the umbilicus.

b) Distance of the inferior epigastric artery from the midline at the level midway between the umbilicus and the pubic symphysis.

c) Distance of the inferior epigastric artery from the midline at the level of the pubic symphysis.

d) Distance from the insertion of the rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin.

IX. Length of the inferior epigastric artery (Fig.4).

a) From the point of origin of the inferior epigastric artery to its entrance into the rectus sheath.

b) From the point of origin of the inferior epigastric artery to its entrance into the rectus muscle substance

X. Diameter of the inferior epigastric artery.

a) At the origin of the inferior epigastric artery.

b) At the entrance of the inferior epigastric artery into the rectus muscle substance.

c) This study is a humble attempt to provide a better understanding of the most important blood vessel of the abdominal wall.

REVIEW OF LITERATURE

I Origin of the inferior epigastric artery

a) from external iliac artery or femoral artery or any other source of origin

b) site of origin from the external iliac artery in relation to the inguinal ligament

Henry Gray (1858) quoted that the inferior epigastric artery arises from the external iliac artery posterior to the inguinal ligament. Sometimes the inferior epigastric artery arises from the femoral artery. It then ascends anterior to the femoral vein, into the abdomen to follow its course.(Fig.6)

Sir Henry Morris (1893) stated that the inferior epigastric artery is one of the branches of the external iliac artery which usually arises just above the inguinal ligament.

D.J.Cunningham (1902) said that the inferior epigastric artery arises from the external iliac artery immediately above the inguinal ligament and runs upwards and medially, along the medial side of the deep inguinal ring, to the deep surface of the rectus abdominis.

A.M.Buchanan (1906) said that the inferior epigastric artery arises from the medial side of the external iliac, about ¼ inch above the inguinal ligament.

Thomas Dwght et al (1907) quoted that the inferior eigastric artery arises from the anterior surface of the external iliac, a short distance above where it passes beneath the inguinal ligament. He also stated that the epigastric

may arise from the external iliac higher up than usual, as high, indeed, as a point 6cm (2 3/8 in) above the inguinal ligament. In such cases it passes downward and forward upon the anterior surface of the external iliac to reach the abdominal wall.

It may also arise below its usual position , that is to say, from the femoral artery and it may be given off from a trunk common to it and the deep circumflex iliac. In addition to being frequently the origin of the obturator, it may be given off from that artery as a result of the enlargement of the anastomoses of the pubic branches of the two arteries and the subsequent degeneration of the proximal portion of the inferior epigastric.

Adachi (1928) described the arterial variation in which the inferior epigastric and obturator arteries arise as a common trunk from the medial circumflex femoral artery.

Dschau (1936) reported a case in which the inferior epigastric and obturator arise from the medial circumflex femoral artery as independent arteries.

R.J.Last (1954) said that the inferior epigastric artery leaves the external iliac at the inguinal ligament, passes upwards behind the conjoint tendon, slips over the semicircular fold and so enters the sheath.

Sir John Bruce,R.Walmsley,J.A.Ross (1964) said that the inferior epigastric artery arises from the external iliac, about 0.5cm above the inguinal ligament.

Giovanni Teodori et al (1984) stated that the origin of the epigastric may take place from any part of the external iliac between Poupart`s ligament and two inches and a half above it; or it may arise below this ligament, from the femoral or from the deep femoral. Sometimes the epigastric arises from the obturator artery, the latter vessel being furnished by the internal iliac, or the epigastric may be formed by two branches, one derived from the external iliac, the other from the internal iliac.

Bergman et al (1984) have noted that the existence of a common origin for the inferior epigastric and obturator arteries is a relatively frequent anomaly, occurring in 20-30% (Fig.7).

George C.Cormack and B.George H.Lamberty (1986) said that the deep inferior epigastric artery leaves the external iliac immediately above the inguinal ligament, ascends obliquely along the medial margin of the deep inguinal ring, and runs forward in the extraperitoneal tissue(forming the lateral umbilical fold).

Emura et al (1989) have reported a trunk for the medial circumflex femoral, inferior epigastric and obturator arteries arising from the femoral artery in one case.

J.R.Sanudo et al (1993) have found during routine dissection two cases of arterial variation in which the obturator, inferior epigastric and medial circumflex femoral arteries arose from a common trunk from the external iliac artery.

Donald Serafin (1996) noted that the deep inferior epigastric artery arises from the medial aspect of the external iliac artery, opposite the origin of the deep circumflex iliac artery approximately 1cm above the inguinal ligament.

Jakubowicz M.Czarniawska-Grzesinska M (1996) have studied the variability in origin and topography of the inferior epigastric and obturator arteries and found that in 4% of cases there was a common trunk for inferior epigastric and obturator arteries.

Bilgic.S.Sahin B (1997) reported a newborn cadaver with a common trunk for the obturator, inferior epigastric and deep femoral arteries arising from the external iliac artery.

Donal Shanahan and R.K.Jordan (1997)have shown that in a male specimen, the inferior epigastric artery was a recurrent branch of an anomalous medial circumflex femoral artery arising from the external iliac artery. This anomalous inferior epigastric artery arose within the femoral triangle and ran superiorly, passing deep to the inguinal ligament, medial to the deep inguinal ring and entered the rectus sheath anterior to the arcuate line.

C.Kopuz et al (2000) reported a case in which the inferior epigastric artery arose from a common trunk with the medial circumflex femoral artery. The common trunk arose from the femoral artery. The inferior epigastric artery reached the anterior abdominal wall by passing deep to the inguinal ligament. The medial circumflex artery ran between the femoral artery and vein within the femoral triangle.

Levent Sarikcioglu and Muzaffer Sindel (2001) have described multiple vessel variations in the retropubic region of a 55yr old male cadaver, in which the obturator artery had its origin from the external iliac artery 2cm above the inguinal ligament and the inferior epigastric artery had its origin from the femoral artery.

Michael S.Baggish and Mickey M.Karram (2001) noted that the inferior epigastric vessels take their origin from the external iliac vessels at a point cranial to the inguinal ligament.

Levent Sarikcioglu et al (2003) reported that out of 54 cadaver halves dissected by them, in 41 halves(76.6%) the inferior epigastric artery originated from the external iliac artery 1.2-2.8cm above the inguinal ligament. In 13 halves (22.2%) the artery originated from the femoral artery 0.8-1.6cm below below the inguinal ligament.

John E.Skandalakis (2004) stated that the inferior epigastric artery arises from the external iliac artery, just above the inguinal ligament.

Ercan Tanyeli et al (2006) during routine dissection found a complex variation of the femoral artery on the left side of a 72 year old male cadaver. The deep femoral artery was originating from the anterior aspect of the femoral artery; the inferior epigastric and the external pudendal arteries were arising from the deep femoral artery. Besides, the lateral circumflex femoral artery was arising from the lateral aspect of the femoral artery and distal to the origin of the deep femoral artery.

II Level of entry into the rectus muscle

W.Henry Hollinshead (1956) said that the superior and the inferior epigastric arteries usually lie at first on the posterior surface of the rectus abdominis muscle; the superior tends to disappear quickly into the muscle, while the inferior tends to enter its middle third.

Frank J.Milloy,Barry J.Anson and David K.McAfee (1960) in a study of 115 cadavers found that the inferior epigastric artery enters the rectus muscle substance in the lower third 28 times(17 percent), in the middle third 126 times(78 percent) and in the upper third 8 times(5 percent).

III Single or Double main stem of inferior epigastric artery

Frank J.Milloy,Barry J.Anson and David K.McAfee(1960) on dissection of 115 cadavers found that as the inferior epigastric artery passed superiorly on the dorsal aspect of the rectus, it was found to consist of a single main stem in 139(86 percent) instances, and of a double main stem in 23(14 percent) instances before entering the muscle substance.

IV Branches of the inferior epigastric artery

Henry Gray (1858) said that the inferior epigastric artery has the following branches: the cremasteric artery, a pubic branch, and muscular and cutaneous branches.

The cremasteric artery accompanies the spermatic cord in males and supplies the cremasteric and other coverings of the cord. It anastomoses with the testicular artery. In females it is small and accompanies the round ligament.

A pubic branch, near the femoral ring, descends posterior to the pubis and anastomoses with the pubic branch of the obturator artery (Fig.8). Muscular branches supply the abdominal muscles and peritoneum, and anastomose with the circumflex iliac and lumbar arteries. Cutaneous branches perforate the aponeuroses of external oblique, supply the skin and anastomose with branches of the superficial epigastric artery.

Sir Henry Morris (1893) stated that the branches of the inferior epigastric artery are small and include a) the external spermatic artery (a.spermatica externa) that runs with the ductus through the inguinal canal, supplies the cremaster muscle, and anastomoses with the internal spermatic, external pudendal, and perineal arteries. In the female, a corresponding artery (a.lig.teretis uteri) accompanies the round ligament of the uterus through the inguinal canal and anastomoses in a similar manner. b) The pubic branch (r.pubicus) that passes below or sometimes above the femoral ring to the back of the pubis, where it anastomoses with the pubic branch of the obturator.

D.J.Cunningham (1902) has described the branches of inferior epigastric artery as muscular and cutaneous branches which supply the anterior abdominal wall. The cremasteric artery in the male (artery of the round ligament of the uterus in the female) is small. In the male, it accompanies the spermatic cord, supplying its coverings, including the cremaster. In the female it runs with the round ligament. The pubic branch descends on either the lateral or the medial side of the femoral ring, to anastomose with the pubic branch of the obturator artery.

A.M.Buchanan (1906) said that the inferior epigastric artery branches are cremasteric, pubic, muscular, cutaneous, peritoneal and terminal or anastomotic.

The cremasteric artery enters the spermatic cord and supplies the cremaster muscle and the other coverings of the cord. The cremasteric artery is replaced in the female by the artery of the ligamentum teres of the uterus.

The pubic artery passes medially behind the medial half of the inguinal ligament to the back of the body of the os pubis, where it anastomoses with the pubic branch of the obturator artery and its fellow of the opposite side. It may pass along the lateral border of the pectineal part of the inguinal (Gimbernat`s) ligament.

The cutaneous branches perforate the rectus and the anterior wall of its sheath to be distributed to the skin, in which they anastomose with branches of the superficial epigastric.

The peritoneal branches pierce the posterior wall of the sheath of the rectus to be distributed to the adjacent parietal peritoneum.

The terminal or anastomotic branches enter the rectus above the level of the umbilicus and anastomose with the superior epigastric of the internal mammary.

Thomas Dwght et al (1907) said that throughout its course the inferior epigastric artery gives off a number of branches.

a) The external spermatic artery (a.spermatica externa in the male, a.ligamenti teretis in the female) is given off a short distance beyond the origin of the inferior epigastric and accompanies the spermatic cord or round ligament of the uterus through the inguinal canal. In the male it supplies the cremaster muscle and the spermatic and deferential arteries, and in the female, in which it is small, it supplies the lower part of the round ligament and terminates in the labium majus by anastomosing with branches of the superficial perineal artery.

b) The pubic branch (ramus pubicus) arises a short distance beyond the external spermatic and, passing either above or below the femoral ring, passes downward and medially upon the posterior surface of the os pubis, where it may anastomose with the pubic branch of the obturator.

c) Muscular branches, variable in number, are given off, for the most part, laterally and supply the muscles of the abdominal wall. They anastomose with branches of the lower intercostal and lumbar arteries.

d) Cutaneous branches, also variable in number, pierce the rectus and the anterior wall of its sheath and supply the skin of the abdomen near the median line.

Russel T.Woodburne (1957) described that several small branches of the inferior epigastric artery arise near its origin. The cremasteric artery accompanies the spermatic cord and supplies the cremaster muscle and the other coverings of the cord. In the female the small corresponding artery of the round ligament reaches the labium majus along the round ligament and anastomoses with the superficial external pudendal artery. A pubic branch of

the inferior epigastric artery runs medialward along the inguinal ligament and then turns inward along the free border of the lacunar ligament to reach the back of the pubis, where it anastomoses with the pubic branch of the obturator artery.

V Abnormal obturator artery

Henry Gray (1858) stated that occasionally, the pubic branch of the inferior epigastric is larger than the main obturator artery and supplies the majority of flow into the vessel as it enters the thigh. It is then referred to as the aberrant obturator artery. It lies close to the medial border of the femoral ring and may be damaged in medial dissection of the ring during femoral hernia repair.

Pfitzner (1889) found an obturator arising from the inferior epigastric or external iliac 152 times in 500, or 30.4 percent, of sides; this abnormal origin frequently seems to be due to the enlargement of a small anastomosis which often normally exists between the small pubic branch of the inferior epigastric artery and the obturator.

Jastchinski (1891), quoted that the course of abnormal obturator artery along the lateral border of the ring is much the most frequent, occurring in 60 percent of cases, and being more frequent in females than in males. The course across the ring occurs in about 22.5 percent of cases, and is again more frequent in females than in males; while the course along the free edge of the lacunar ligament occurs in only 17.5 percent of cases, and is more common in

males than in females. The differences in the two sexes are associated with the differences in the form of the pelvis and of the obturator foramen.

Sir Henry Morris (1893) said that the pubic branch (r.pubicus) that passes below or sometimes above the femoral ring to the back of the pubis, and anastomoses with the pubic branch of the obturator. This branch, though usually small, is occasionally considerably enlarged. Then its exact course becomes of great interest to the surgeon. Thus it may descend on the medial side of the femoral vein, and therefore lateral to the side of the femoral ring, or it may course medially in front of the femoral ring and turn downward either behind the os pubis or immediately behind the free edge of the lacunar (Gimbernat`s) ligament, in which situation it would be exposed to injury in the operation for the relief of a strangulated femoral hernia. In such cases the obturator may not be connected with the hypogastric artery at all, but may take origin entirely from the external iliac or from the inferior epigastric. This abnormal origin of the obturator occurs in about 37 percent of all subjects, but the abnormal artery courses around the medial side of the femoral ring in which situation it is liable to injury in operation for femoral hernia in a portion of these cases only.

Parson and Keith (1897) stated in their report that in 138 subjects examined, the obturator was seen to arise from inferior epigastric artery only 11 times (8%).

D.J.Cunningham (1902) said that in some instances the obturator artery arises from the inferior epigastric artery instead of from the internal iliac. The course of such an abnormal obturator artery is of surgical importance. From its

origin it descends on the medial side of the external iliac vein, and usually on the lateral side of the femoral ring; but in 30 percent of cases, and more often in males than in females, it descends on the medial side of the ring and may be injured in the operation for the relief of a strangulated femoral hernia.

Thomas Dwght et al (1907) stated that the origin of the obturator from the inferior epigastric artery becomes of importance from the fact that in order to reach its point of exit from the pelvis, the obturator canal, the vessel must come into intimate relations with the femoral ring, and may thus add an important complication to the operation for the relief of femoral hernia. There are three possible courses for the vessel in relation to the ring. 1) it may pass medially from its origin over the upper border of the ring and then curve downward along the free border of the lacunar ligament to reach the obturator canal. 2) it may bend downward abruptly at its origin and pass in an almost direct course to the obturator canal, passing over the inner surface of the external iliac vein, and therefore down the lateral border of crural ring; or 3) it may pass directly across the ring.

J.C.Boileau Grant (1937) said that the obturator artery runs forwards on the side wall of the pelvis to the obturator foramen. It lies between its nerve and vein. The obturator and inferior epigastric arteries both supply branches to the back of the pubis. These pubic branches anastomose, and the anastomotic channel is commonly (33%) so abnormally large that the obturator artery derives its blood from the epigastric arery and only slightly, if at all, from the internal iliac artery. This is known as an abnormal obturator artery. The obturator vein likewise is commonly abnormal.

Arthur H.Curtis, Barry J Anson et al (1942) in a gynaecological survey found that the origin of the obturator from the inferior epigastric occurred in approximately one-fourth of laboratory specimens.

J.L.Braithwaite (1952) in a study of 169 pelvic halves found that the obturator artery arises from the inferior epigastric artery in 19.5% cases.

R.J.Last (1954) stated that the obturator artery passes along the sidewall of the pelvis below the nerve to enter the obturator foramen with the artery and vein and pass into the thigh. The artery gives off a small branch to the periosteum of the back of the pubis, and this vessel anastomoses with the pubic branch of the inferior epigastric artery. In about 50% of cases this anastomotic connexion opens up to become the accessory or abnormal obturator artery, replacing the normal branch from the internal iliac. In its passage from the inferior epigastric to the obturator foramen, it usually passes on the lateral side of the femoral ring, ie.,adjacent to the external iliac vein. When it lies at the medial side of the ring, alongside the edge of the lacunar ligament, it is vulnerable to injury or division if the ligament has to be incised to release a strangulated femoral hernia.

W.Henry Hollinshead (1956) stated that the usual origin of the obturator artery is from the internal iliac or one of its branches, but in an appreciable number of cases this origin is absent or poorly developed, and the obturator artery arises primarily or entirely from the inferior epigastric artery or the external iliac artery. (Fig.9) Even with this abnormal origin, however, the relationship of the obturator artery to the femoral canal varies. More commonly, the abnormally arising artery tends to parallel the inguinal ligament

after passing in front of the external iliac vein, and therefoe passes in front of the femoral ring. Thus an obturator artery of anomalous origin may have a very close but unpredictable relation to the mouth of a femoral hernial sac.

J.D.Boyd et al (1956) stated that the obturator artery while in the pelvis gives a small pubic branch, which anastomoses with a similar branch of the inferior epigastric artery. Enlargement of this anastomosis constitutes the abnormal obturator artery, which because of its proximity to the femoral ring, may be of practical importance in operations on femoral hernia.

Robert F.Muller and Melvin M.Figley (1957) undertook a study of 182 technically satisfactory aortographic examinations in 173 patients and found that in 37 percent of cases, the obturator arises from the inferior epigastric artery, the deep circumflex iliac artery, or directly from the external iliac artery, and as such is known as an aberrant obturator.

Russel T.Woodburne (1957) stated an abnormal obturator artery occurs in a high percentage of cases. Such a vessel takes its origin from the inferior epigastric artery or, rarely, the external iliac artery and descends across the brim of the pelvis to the obturator foramen. Its presence is due to the enlargement of the normal anastomoses of the pubic branches of the inferior epigastric and obturator arteries, so that a vessel of considerable size is formed. The particular significance of the ‘abnormal’ obturator artery is that it may pass toward the lacunar ligament and thus lie at the medial edge of femoral ring; it is in danger if that ring has to be enlarged to free the sac of a femoral hernia.

R.D.Lockhart,G.F.Hamilton and F.W.Fyfe (1959) said that the pubic branch of the obturator artery crosses the pelvic surface of the pubis, anastomosing with the pubic branch of the inferior epigastric artery,a communication which may replace the usual origin of the obturator artery from the internal iliac artery so forming an abnormal obturator artery, the course of which may be lateral or medial to the femoral ring-a point to be remembered in the surgical treatment of femoral hernia.

Ernest Gardner, Donald J.Gray and Ronan O Rahilly (1960) stated that the obturator artery arises from the inferior epigastric in about one-fifth of instances. It then passes on either the lateral or medial side of the femoral ring before reaching the obturator foramen. A medially placed obturator artery is especially susceptible to damage during operations for femoral hernia.

Harold Ellis (1960) told that normally there is an anastomosis between the pubic branch of the inferior epigastric artery and the pubic branch of the obturator artery. Occasionally the obturator artery is entirely replaced by this branch from the inferior epigastric –the abnormal obturator artery. This aberrant vessel usually passes laterally to the femoral canal and is out of harm`s way;more rarely it passes behind Gimbernat`s ligament and it is then in surgical danger.

Sir Solly Zuckerman (1961) noted that the pubic branch of the inferior epigastric artery is of some importance since, by its enlargement and anastomosis with an enlarged pubic branch of the obturator artery, it sometimes forms a large abnormal obturator artery which replaces the normal obturator artery.

John E.Skandalakis & Stephen W.Gray (1974) said that they preferred to divide the inguinal ligament instead of the lacunar ligament in the operation for incarcerated femoral hernia, because an aberrant obturator artery, arising from the inferior epigastric artery, may pass medial to the femoral ring in the edge of the lacunar ligament rather than lateral to the ring. Injury to this vessel will cause unnecessary complications (Fig.10).

Lee McGregor (1975) said that usually the obturator and inferior epigastric vessels each gives a pubic branch which is small, and these anastomose at the back of the pubis. In 30 percent of cases the pubic branch of the inferior epigastric is very large, taking the place of the obturator artery, and being known as the abnormal obturator artery. It passes down in relation to the femoral ring to reach the obturator foramen. In its descent it may stick to the side of the femoral vein (the safe position). In 10 percent of persons with such an abnormal artery, the vessel passes down along the edge of the lacunar ligament, which is the inner boundary of the femoral ring (the dangerous position). In strangulated femoral hernia the constricting agent is sometimes the outer edge of the lacunar ligament, and it must be divided to relieve the pressure. It is necessary, therefore, in cases where an abnormal artery exists, to exercise great care in dealing with this ligament , as serious haemorrage follows division of the vessel.

B.Page & Patrick (2003) mentioned that an abnormal obturator artery arising from the inferior epigastric is observed in about 30 percent of cases.

Suppa-ut Pungapong and Sathon Thum-umnauysuk (2005) in a study of 33 cadavers (66 half pelvises) fifteen males (30 half pelvises) and eighteen female (36 half pelvises) found the aberrant obturator artery in 13.6% (9/66) cases .21.2% in males(7/33) and5.5% in females(2/36).

VI Pattern of Anastomosis of the inferior epigastric artery with the superior epigastric artery

Frank J.Milloy, Barry J.Anson and David K.McAfee (1960) in a study of 115 cadavers have mentioned gross anastomosis of the superior and inferior deep epigastric arteries was found in 40% cases.

No anastomosis was found in 60%

The pattern of anastomoses (Fig.11) revealed by dissection by them is

1 anastomosis-18.3%, 2 anastomoses-18.3%, Multiple anastomoses-3.3%.

Moon H K, Taylor G I (1988) performed radiographic studies in 64 fresh cadavers. The patterns of anastomosis between the deep superior epigastric artery and the deep inferior epigastric artery were noted. Type I (29 percent) revealed a single deep superior epigastric artery and deep inferior epigastric artery, type II (57 percent) revealed a double branched system of each vessel, and type III (14 percent) revealed a system of three or more major branches.

VII. Level of Anastomosis

A.M.Buchanan (1906) said that the inferior epigastric artery ascends vertically between the muscle and the posterior wall of the sheath as high as the umbilicus. Here it enters the muscle and about 2 inches above the umbilicus ends in its terminal branches which anastomose with branches of the superior epigastric artery.

W.Henry Hollinshead(1956) noted that the blood supply of the rectus muscle is through the superior epigastric (from the internal mammary) and the inferior epigastric from the iliohypogastric. Their terminal branches anastomose in the muscle at about the level of the umbilicus, and through this anastomosis a collateral channel between the subclavian and external iliac arteries is formed.

Frank J.Milloy, Barry J Anson and David K.McAfee (1960) stated that the superior epigastric artery anastomoses with the inferior epigastric artery regularly at a more cranial level to the umbilicus.

Giovanni Teodori et al (1984) said that the inferior epigastric artery perforates the rectus sheath near its lower third, it runs vertically upwards behind the rectus, to which it is distributed and it divides into numerous branches which anastomose above the umbilicus with the terminal branches of the internal thoracic artery and inferior intercostal arteries (Fig.12).

George C.Cormack and B.George H.Lamberty (1986) stated that in passing medially the inferior epigastric artery pierces the transversalis fascia and enters the rectus sheath. Above the level of the umbilicus its terminal divisions form an anastomosis with branches of the superior epigastric artery.

Berish Strauch, Han-Liang et al (1993) said that generally, the inferior epigastric artery divides into two or three large branches below the level of the umbilicus. These vessels pass upward in the muscle to communicate with the superior epigastric system above the level of the umbilicus.

Donald Serafin (1996) observed that on entering the rectus sheath, the deep inferior epigastric artery courses cephalad for a variable distance on the posterior aspect of the muscle before penetrating it. Within the substance of the muscle, it usually gives rise to two branches below the umbilicus- a medial and a lateral branch, which continue to course cephalad.

The lateral branch usually gives rise to lateral segmental arteries (which accompany segmental nerves), which communicate with deep intercostal arteries coursing in a plane between the internal oblique and transversus abdominis muscles. Throughout its course, the lateral branch gives rise to multiple muscle and musculocutaneous perforating vessels, eventually terminating in a periumbilical perforating artery.

After sending a major branch to the umbilicus, the medial branch continues cephalad, giving rise to multiple muscle and musculocutaneous perforating vessels. The medial branch then continues cephalad, terminating in multiple choke vessels, which communicate directly with terminal vessels of the deep superior epigastric artery in the watershed within the rectus abdominis muscle midway between the xiphoid process and the umbilicus.

Boyd J B, Taylor G I, Corlett R (2002) investigated the vascular territories of the superior and inferior epigastric arteries by dye injection, dissection and barium radiographic studies.They found the connections between the superior and the deep inferior epigastric arteries within the rectus abdominis muscle well above the level of the umbilicus.

John E.Skandalakis (2004) stated that the superior and inferior epigastric vessels anastomose at approximately the middle one-third of the muscle.

D.M.O`Dey et al (2004) investigated the arterial vascularisation of the abdominal wall with special regard to the umbilicus, by a study of 12 cadavers. The abdominal walls were resected enbloc and x-ray photographs were taken by conventional and mammographic technique. They found that the anastomosis between the inferior and superior epigastric artery is located above the umbilicus.

Gagnon, A.R, Blondeel, P.N (2006) said that the internal mammary artery continues in the abdomen as the superior epigastric artery to finally coalesce into a watershed area midway between the xiphoid process and the umbilicus. In this region, multiple anastomotic channels exist between the superior and the inferior epigastric systems.

VIII. Distance of the inferior epigastric artery from the important landmarks of the abdomen and pelvis

TeLinde Richard W (1894) stated that lateral laparoscopic trocars are placed in a region of the lower abdomen where injury to the inferior epigastric and superficial epigastric vessels can occur easily. The inferior epigastric arteries and the superficial epigastric arteries run similar courses toward the umbilicus. Knowing the average location of these blood vessels helps in choosing insertion sites that will minimize their injury and the potential haemorrhage and hematomas that this injury can cause. Just above the pubic symphysis, the vessels lie approximately 5.5cm from the midline, whereas at the level of the umbilicus, they are 4.5cm from the midline.

A.M.Buchanan (1906) mentioned that the course of the inferior epigastric artery in its first or oblique part is indicated by a line from the medial border of the deep inguinal ring to the lateral border of the rectus abdominis at a point about midway between the umbilicus and the superior border of the symphysis pubis. The course of the second or vertical part of the vessel is represented by a line corresponding with the centre of the rectus and about 1 ½ inches from the linea alba.

J.C.Boileau Grant (1937) said that the lateral border of the rectus is a nearly bloodless line, because very few branches of the epigastric arteries cross it and anastomose with the intercostal and lumbar arteries.

Frank J.Milloy,Barry J.Anson and David K.McAfee (1960) said that the deep inferior epigastric artery arises from the external iliac artery just before it passes beneath Poupart`s ligament, and approaches the rectus abdominis from its lateral aspect. The distance from the insertion of the rectus tendon to the intersection of this artery with the lateral rectus margin-the medial side of Hesselbach`s triangle- was measured and it was between 2-10cm. In 1 case the artery lay dorsal to the tendon and muscle entirely, and thus there was no triangle.

Hurd,William et al (1994) reviewed the abdominal computed tomographic images of 21 reproductive aged women to determine the location of the inferior epigastric artery and found that the artery was 5.6$\pm$1.0cm (mean$\pm$SD) from the midline just above the pubic symphysis.

Michael S. Baggish and Mickey M.Karram(2001) quoted that the distance from the midline 4 cm above the upper margin of the symphysis pubis to the inferior epigastric vessels is 6-7cm.

Alan A.Saber et al (2004) studied the abdominal and pelvic CT images of 100 patients to determine the location of the superior and inferior epigastric vessels from the midline at five different levels. At the xiphoid level, the average distance of the epigastric vessels from the midline was 4.41cm on the right and 4.53cm on the left side. At the level midway between the xiphoid and the umbilicus, the epigastric vessels on the right was 5.50cm and 5.36cm on the left. At the umbilicus, the epigastric vessels on the right was 5.88cm and 5.55cm on the left from the midline. Midway between the umbilicus and symphysis pubis, the right epigastric vessel was located 5.32cm from the midline and 5.25cm on the left. The epigastric vessels were farthest from the midline at the symphysis pubis level for both the right and left side. The epigastric vessels were 7.47cm and 7.49cm on the right side and left side respectively, at the level of the symphysis pubis. (Fig.13)

IX. Length of the inferior epigastric artery

E.Migalter et al(1992) harvested fifty seven inferior epigastric arteries from 47 adults for evaluating the artery as an alternative arterial conduit for CABG. He said that the usable length of inferior epigastric artery in CABG is 6 to 16cm(mean 11+0.25cm).

Berish Strauch, Han-Liang et al(1993) stated that the average length of inferior epigastric artery from its origin to its entrance into the rectus is 10.9cm (range 7.1 to 14.7cm).

Watanabe et al (1994) did a study on the use of inferior epigastric artery for coronary artery bypass grafting and noted that the mean length is 12.2cm.

Donald Serafin (1996) noted that from its point of origin to its entrance into the rectus sheath, the inferior epigastric artery length is 7.6cm.

Kim DI et al (2003) performed forty nine cadaver dissections (male 30,female 19) to identify the shape and size of rectus abdominis muscle and the distribution of vessels in Korean for flap surgery. The length between the origin of inferior epigastric artery and the point of semilunar line met inferior epigastric artery was 4cm.

Gagnon,A.R, Blondeell,P.N (2006) while evaluating the musculocutaneous flaps vascularised by the inferior epigastric artery for plastic surgical reconstruction, found that the usable length of inferior epigastric artery is 10 to 14cm.

X. Vessel diameter

E.Migalter et al (1992) evaluated the inferior epigastric artery as an alternative arterial conduit for coronary bypass grafting and found the diameter was 2.5 to 3.5mm proximally and 2 to 3mm distally in 57 arteries harvested.

Berish Strauch, Han-Liang et al(1993) quoted that the diameter of inferior epigastric artery at the origin and entrance are respectively, 2.7mm(range 1.6 to 3.5mm) and 2.0mm(range 1.5 to 2.6mm).

George C.Cormack and B.George H.Lamberty(1986) stated that the external diameter at its point of origin of the inferior epigastric artery measures 3.4mm.

Donald Serafin (1996) said that at its origin, the deep inferior epigastric artery measures an average of 3.4mm in external diameter.

Kim D I et al (2003) in a morphological study of the rectus abdominis muscle for flap sugery, performed 49 cadaveric dissections and found the external diameter of inferior epigastric artery to be 2.6±0.6mm.

John E Skandalakis (2004) noted that the average diameter of inferior epigastric artery is 3.4mm.

Gagnon, A.R, Blondeell, P.N (2006) while evaluating the musculocutaneous flaps vascularised by the inferior epigastric artery for plastic surgical reconstruction, found that the diameter of the artery at its artery was 3 -3.5mm.

Histology Review

Giovanni Teodori et al (1984) stated that the internal elastic lamina of the inferior epigastric artery showed good development equivalent to the internal thoracic artery. Tunica media of the inferior epigastric artery is poor in elastic fibres and rich in smooth muscle cells compared with the internal thoracic artery. The intima of inferior epigastric artery is less thin than internal thoracic artery but it presents less fenestrations than internal thoracic artery ,and the combined thickness of media and intima is lower than internal thoracic artery (0.2mm vs 0.3mm).

A. Wahba et al (1994) did a morphometric evaluation of the intima and media of the inferior epigastric artery and the internal thoracic artery in 45 post mortem examinations, as both the arteries are used as a conduit for myocardial revascularization. The intima of the inferior epigastric artery showed a lower degree of intimal thickening than the internal thoracic artery. The internal thoracic artery contained significantly more elastic layers than the inferior epigastric artery.The internal thoracic artery revealed the typical structure of an elastic artery and inferior epigastric artery had a distinctly different structure resembling the muscular artery pattern.

EMBRYOLOGY

During the fourth week of intrauterine life, previous to the fusion of the dorsal aortae, each dorsal aorta bears dorsal, lateral and ventral branches. These are repeated serially and each set is arranged in a longitudinal row. After the fusion of the dorsal aortae during the fifth to seventh weeks of embryonic life, transformation of these paired arteries to more specialized vessels occurs.

Each primitive dorsal aorta gives off ventral splanchnic arteries (paired splanchnic branches to the digestive tube), lateral splanchnic arteries (paired segmental branches to the mesonephric ridge), somatic arteries (intersegmental branches to the body wall) and a caudal continuation (which passes into the body stalk), the umbilical arteries (Fig.14).

The somatic arteries are intersegmental in position. They persist unchanged, in the thoracic and lumbar regions, as the posterior intercostal, subcostal and lumbar arteries. Each gives off a dorsal ramus which passes backwards in the intersegmental interval and divides into medial and lateral branches to supply the muscles and superficial tissues of the back (Fig.15). Having produced its dorsal branch, the intersegmental artery runs ventrally in the body wall, gives off a lateral branch and terminates in muscular and cutaneous rami.

Numerous longitudinal anastomoses link up the intersegmental arteries and their branches. Near the anterior median line, the intersegmental arteries are linked by a ventral somatic anastomoses. At the thoracic level the new

longitudinal vessel thus formed is known as the internal thoracic artery; more caudally it is continued as the **SUPERIOR AND INFERIOR EPIGASTRIC ARTERIES**.

Leslie Brainerd Arey (1924) stated that anomalous blood vessels are of common occurrence. They may be due to

1. to the choice of unusual paths in the primitive vascular plexuses.
2. to the persistence of vessels normally obliterated.
3. to the disappearance of vessels normally retained.
4. to incomplete development and
5. to fusions and absorptions of parts usually distinct.

He also stated that the embryologic development of the vascular plexus of the lower limb is based on an unusual selection of channels, some of which enlarge while the others contract and disappear, thereby establishing the final pattern. Before pelvic and femoral arteries appear as independent blood vessels from the rete pelvicum and rete femorale respectively, the blood flow destined for this territory makes an unexpected choice of source channels. The origination of the obturator artery from external iliac artery and inferior epigastric artery from femoral artery may be caused by such an unusual selection of channels.

MATERIALS AND METHODS

STUDY MATERIALS

1. 50 adult specimens from 16 male and 9 female cadavers.

2. 6 foetal specimens from 2 male and 1 female cadavers.

3. 10 adult abdominal angiograms.

4. 8 lower limb and 2 abdominal 64 slice CT angiograms.

METHODS OF STUDY

A. Dissection Method

   1 Conventional dissection method

   2 Predissectional dye injection method

B. Radiological study

   1 Adult clinical routine angiographic study

   2 Adult cadaveric abdominal wall angiography

   3 Adult clinical 64 slice CT angiographic study

C. Histological study

SPECIMEN COLLECTION

1. Twenty five adult embalmed human cadavers were selected from the cadavers allotted to the first MBBS students and first BDS students at the Institute of Anatomy, Madras Medical College, Chennai-3.

2. Three dead unclaimed fetuses, all from 7 to 9 months gestational age were obtained from the Institute of Obstetrics and Gynaecology Egmore. Fetal embalming was done by injecting 200 ml of embalming fluid consisting of formalin, glycerol, alcohol and thymol , through the aorta.

A. DISSECTION METHOD

1. Conventional dissection method

The adult cadaver was placed in the supine position. A midline skin incision was made from the xiphisternum to the pubic symphysis, encircling the umbilicus.

From the upper end of the incision, a transverse incision was made laterally until stopped by the table. From the lower end another transverse incision was made along the pubic crest, and from the pubic tubercle to the anterior superior iliac spine below the inguinal ligament and along the iliac crest.

The skin was reflected laterally. The two layers of superficial fascia, fatty Camper`s fascia and membranous Scarpa`s fascia were reflected laterally. The external oblique muscle and aponeurosis were separated from the internal oblique starting from the linea semilunaris and reflected laterally. Likewise the

internal oblique was separated from the transverses abdominis muscle and reflected laterally from the lateral margin of rectus muscle. The transverses abdominis was also reflected. By now the inferior epigastric became exposed in the extraperitoneal tissue arising from the external iliac artery behind the inguinal ligament.

By careful dissection, the origin of the inferior epigastric artery was identified and the distance of the origin of the inferior epigastric artery from the inguinal ligament at the point where the external iliac artery enters deep to the inguinal ligament was measured. The spermatic cord (or round ligament of uterus) was identified lateral to the inferior epigastric artery and coursing anterior to it (Pic.4). The artery was seen ascending medially piercing the fascia transversalis.

The first branch, the cremasteric artery (or artery to round ligament of uterus) was seen accompanying the spermatic cord. The next branch, pubic branch was identified which arose soon after the cremasteric and passed behind the inguinal ligament medially, then behind the superior pubic ramus to anastomose with the pubic branch of the obturator artery. In some cases the pubic branch was enlarged and when followed, it was traced to the obturator canal, entering it. The relation of this pubic branch to the femoral ring was observed and noted.

The inferior epigastric artery was traced further medially and carefully observed for the presence of double stem and noted. The artery length from the origin to the lateral rectus margin was measured with a thread and scale and the measurements noted (Pic.3).

The distance from the insertion of rectus tendon to the intersection of the lateral rectus margin by the inferior epigastric artery and the distance from the origin of the inferior epigastric artery to the pubic symphysis were also measured by the same method and the observations recorded (Pic.6).

The inferior epigastric artery was accompanied by a pair of venae commitantes. A vertical incision was made from xiphisternum to the pubic symphysis on the anterior rectus sheath encircling the umbilicus. The anterior rectus sheath was dissected at the tendinous insertions and removed. The posterior layer of the rectus sheath was examined and the arcuate line identified. The inferior epigastric artery entered the posterior rectus sheath after crossing the arcuate line (Pic.3,5) and ascended vertically for a considerable distance before piercing the rectus muscle. The level of entry into rectus muscle – whether it is at the lower, middle or upper third of the muscle was noted. Pictures were taken then and there.

When lying on the posterior rectus sheath, the artery gave off many lateral branches to the external oblique, internal oblique and the transverses abdominis muscles and some medial branches to the rectus muscle and the umbilicus. Cutaneous perforators and peritoneal perforators were also seen by meticulous dissection. At or above the level of the umbilicus the inferior epigastric artery anastomosed with the superior epigastric artery. The level of anastomoses in relation to the umbilicus and the pattern of anastomoses were carefully noted and recorded. The length of the artery from the origin to its entrance into the rectus muscle, the distance between the artery and the umbilicus, the distance between the artery and midway between the umbilicus and the pubic symphysis were measured and the observations noted.

In the fetal specimens predissectional redlatex injection was done for better identification of the minute artery. Same procedure as done in adult dissection was repeated but with utmost gentleness and care and pictures were taken (Pic.1, 2).

2. Predissectional dye injection method

a. Bull`s fat with redoxide injection

Before dissection, bull`s fat with redoxide was injected in 10 specimens of 5 cadavers.

The dye was prepared from redoxide 100gm; bull's fat 200gm; groundnut oil 100ml and turpentine oil 75ml. The first three components were mixed together, boiled and filtered. Turpentine oil was then added.

The 10 specimens to be injected with the dye were washed and the external iliac artery was exposed with the origin of the inferior epigastric artery. The femoral artery was ligated just below the inguinal ligament to avoid the dye from entering the femoral artery. A 30ml glass syringe with polythene cannula attached at its tip was filled with normal saline. Saline was injected into the external iliac artery with the cannula close to the origin of the inferior epigastric artery, and the saline was aspirated out. This was repeated till the aspirated fluid was free of clot and debris. All the 10 sides were prepared by the same procedure. Then about 30ml of the dye mixture was injected rapidly into the inferior epigastric artery with a 30ml metal syringe when the dye mixture was hot and in liquid form, before it solidified. The dye was allowed to settle down for atleast six hours and again the specimens were preserved in 10% formalin for 2 days. Then after 2 days, dissection of the inferior epigastric artery was carried out.

b. Red latex injection

Latex used for commercial purpose was mixed with red ink and injected into the external iliac artery through a fine caliber rubber cannula at the origin of the inferior epigastric artery after tying the femoral artery and a thorough saline wash. This was done in the fetal specimens for better visualization of the inferior epigastric artery and its branches.

B. RADIOLOGICAL STUDY

1. Adult clinical routine angiographic study

Adult abdominal and pelvic angiograms done at the Barnard Institute of Radiology, Government general Hospital, Chennai were observed in10 patients who underwent the procedure for various reasons, both prophylactic and therapeutic.

The procedure was done by Seldinger`s technique. The examination was performed under local anaesthesia. First the patient was put in supine position. Under aseptic precautions, the anaesthetic agent was infiltrated into the subcutaneous tissues. A small superficial skin nick was made with no.11 blade directly over the femoral arterial pulse.

The course of the artery was palpated while an 18 gauge needle stylet was rapidly thrust down the artery. The needle was gently advanced and when the arterial blood splurt was seen exiting from the stylet hub, the hub was removed and a 0.035 inch guide wire was carefully inserted into the artery without force. The entire procedure was done under fluoroscopic guidance .The

position of the guide wire was viewed by fluoroscopy and advanced. A vessel dilator was introduced over the guide wire. Guidance systems altering the curvature of the catheter tip by means of tip deflector were used to help engage the desired vessel. Through the femoral artery, the contrast material omnipaque (iohexol) was injected and serial pictures taken.

2. Adult cadaveric abdominal wall angiogram

The abdominal wall of 3 cadavers were cut enbloc along with part of external iliac artery 5cm above the inguinal ligament and the femoral artery 2cm below the inguinal ligament, and washed thoroughly. The external iliac artery was tied and through the femoral artery, a large plastic cannula was inserted and saline wash given by injecting and aspirating the fluid till the aspirated fluid was free of clot and debris. The abdominal walls were then carried in a polythene cover to the Barnard Institute of Radiology.

An 18 gauge needle was introduced into the external iliac artery after tying the femoral artery distal to the injection site and the external iliac artery proximal to the injection site. The needle was directed to the inferior epigastric artery and omnipaque was injected and pictures taken.

3. Adult clinical 64 slice CT Angiogram

CT images of abdominal and lower limb angiograms of 10 patients who had undergone the procedure for various reasons were selected and the inferior epigastric arteries were photographed and studied.

CT angiography combines the technology of a conventional CT scan with that of traditional angiography to create detailed images of the blood vessels in the body.

The speed of the 64 slice CT scanner can gather high resolution multidimensional images from different angles around the body in a few seconds. A scan of the whole body takes 30 seconds. The image data is processed by a computer.

The CT scanner is a specialized x-ray machine that is spherical in shape with a mobile flat bed. The bed moves into the CT scan tunnel where the images are obtained. The patient is asked to lie down on the table. An intravenous line is usually started in the arm and the IV tubing is connected to an automatic injector machine. Once everything is ready, the patient is moved into the tunnel and the dye (omnipaque) is injected. The CT scan rapidly obtains images during this period. The images are reconstructed by a computer for 3D viewing.

C. HISTOLOGICAL STUDY

Three bits of the inferior epigastric arteries and three bits of internal thoracic artery 1cm in length were taken from fresh cadavers and processed for histological study. The tissue sections were stained with eosin and haematoxylin and observed under the light microscope.

OBSERVATION

The inferior epigastric arteries in fifty specimens comprising of 25 adult human cadavers (16 male and 9 female) preserved in formalin were studied. Of these, conventional dissection method was carried out in 40 specimens. Predissectional redoxide with bull's fat mixture injection was carried out in 10 specimens to study the branches of the inferior epigastric artery. 3 fetuses (2 male and 1 female) were also dissected and studied. The findings of the dissection are summarized as follows.

I. Origin of the inferior epigastric artery

a) From the external iliac artery or any other source of origin

The inferior epigastric artery was found to arise from the anteromedial surface of external iliac artery in all the fifty adult specimens in this present study (Pic.7).

b) Site of origin from the external iliac artery in relation to the inguinal ligament.

The external iliac artery passes beneath the inguinal ligament and continues as the femoral artery. The inferior epigastric artery was seen to arise from the external iliac artery at the level of the inguinal ligament in 23 (46%) adult specimens dissected (Pic.8). In the remaining 27 (54%) specimens, the inferior epigastric artery arose from the external iliac artery above the level of the inguinal ligament (Table No.1, Chart No.1) (Pic.10).

The distance of the origin of the inferior epigastric arteries above the inguinal ligament was between 0.5 to 2 cm (Pic.9). The average distance was found to be 1.1 cm. The distances above the inguinal ligament are tabulated in Table No.2.

In all the 6 **foetal specimens**, the inferior epigastric artery arose from the external iliac artery.

In 2 fetal specimens, the inferior epigastric artery arose 0.4 cm above the inguinal ligament. In the rest of the 4 specimens it arose at the level of the inguinal ligament.

II. Level of entry into the rectus muscle- upper, middle, or lower third.

In the fifty adult specimens dissected, the inferior epigastric artery was seen to enter the rectus muscle substance in the upper third in 4 (8%) cases (Pic.12) The inferior epigastric artery entered in the middle third of rectus abdominis in 36 (72%)cases, and in the lower third in 10 (20%) cases (Table No.3, Chart No.2) (Pic.11,13,14).

In all the 6 **foetal specimens** the inferior epigastric arteries entered the middle third of the rectus muscle.

III. Single or double stem of the inferior epigastric artery before entering the rectus muscle substance

The inferior epigastric artery was found to have a double stem before entering the rectus muscle substance in 7 specimens (14%) (Pic.16,17). In two cadavers the double stem was bilateral observed both in right and left sides, and in three cadavers it was unilateral (Pic.18).

The artery had a single stem before entering the rectus muscle susbstance in 43 specimens (86%) (Chart No.3) (Pic.15).

There was a single stem before entering the rectus muscle in all the six **foetal specimens**.

IV. Branches of the inferior epigastric artery

The inferior epigastric artery was found to have the following branches in all the 50 adult specimens dissected.

The cremasteric, pubic, muscular, cutaneous, peritoneal and anastomotic branches.

The cremasteric artery was the first branch which accompanied the spermatic cord in the male and the artery of the round ligament of the uterus in the female (Pic.19).

In 42 specimens the pubic artery passed medially behind the body of the pubis to anastomose with the pubic branch of the obturator artery. In 8 specimens the pubic branch was large and entered into the obturator canal.

The muscular branches chiefly arose from the lateral side of the inferior epigastric artery to supply the two obliques, transversus and rectus muscles. The medial branches went on to supply the rectus muscle and the umbilicus (Piic.20, 21).

The cutaneous branches perforated the rectus and the anterior wall of its sheath to supply the skin.

The peritoneal branches were seen piercing the posterior wall of the sheath.

The terminal or anastomotic branches anastomosed with the branches of the superior epigastric artery.

There was a cremasteric (artery of round ligament of uterus in female) branch and a pubic branch in the 6 **foetal specimens**. The muscular, cutaneous, peritoneal and anastomotic branches were very slender.

V. Abnormal obturator artery

In 8 cases the pubic branch of the inferior epigastric artery was enlarged and replaced the obturator artery to enter the obturator canal and supplied the medial part of the thigh (Pic.22).

This abnormal obturator artery was found in this study in (16%). Of these in one male cadaver the abnormal obturator artery was found on both sides (Pic.24).

Among the 8 specimens, the abnormal obturator artery was descending along the medial border of the femoral ring in only one specimen(12.5%) (Pic.25). In the remaining 7 cases it was related to lateral border of the femoral ring (87.5%) (Pic.26) (Chart.4).

The abnormal obturator artery was found in 5 male adult cadaveric halves (5/25) 32% and in 3 female adult cadaveric halves(3/25) 12%.

In only one **foetal specimen**, the pubic branch was enlarged and was seen entering the obturator canal, and hence had become the abnormal obturator artery. It was passing along the lateral border of the femoral ring. In the rest of the 5 fetal specimens the pubic branch of the inferior epigastric artery was of normal size (Pic.23).

VI. Pattern of anastomoses of the inferior epigastric artery with the superior epigastric artery

Dissecting the termination of the inferior epigastric artery was extremely difficult because of the thin caliber of the anastomosing vessels within the rectus muscle substance.

Of the 50 adult specimens,in 36 specimens, no anastomosis was seen (72%). In these 36 specimens, the inferior epigastric vessels could be seen dividing into 2 or 3 terminal branches which ended by supplying the rectus abdominis above the umbilicus. The superior epigastric artery was identified some distance from the termination of the inferior epigastric artery.(Pic.27,Table No.4)

Gross anastomoses between the inferior epigastric artery and superior epigastric artery was seen in 14 specimens only (28%).

Among the cases with anastomoses, in 8 specimens(16%) the inferior epigastric artery ended in 2 terminal branches and the superior epigastric artery also had 2 terminal branches, but only one terminal branch from each of them communicated with each other.(Pic.28)

In 5 cases(10%) both the terminal branches of the inferior epigastric artery and superior epigastric artery anastomosed with each other.(Pic.29)

In 1 case(2%), 3 terminal branches of the inferior epigastric artery anastomosed with 3 branches of the superior epigastric artery.(Pic.30)

In the 6 **foetal specimens**, no gross anastomoses between the inferior epigastric artery and the superior epigastric artery was seen.

VII. Level of anastomoses-at or above the level of umbilicus

Gross anastomoses between the inferior epigastric artery and the superior epigastric artery was seen in 14 specimens (28%). In all the 14 specimens the anastomoses between the inferior epigastric artery and the superior epigastric artery was seen above the level of the umbilicus.(Pic.31)

In the 6 **foetal specimens** the inferior epigastric vessels traversed the rectus muscle above the umbilicus but did not anastomose with the superior epigastric artery.

VIII. Distance of the inferior epigastric artery from the important landmarks of the anterior abdominal wall

1. At the level of the umbilicus, the distance of the inferior epigastric artery from the midline varied from a minimum distance of 3.4 cm to a maximum distance of 4 cm on the right side and from a minimum distance of 3.2 cm to a maximum distance of 4 cm on the left side. Mean $\pm$SD was 3.6$\pm$0.2 cm on the right side, and 3.5$\pm$0.2cm on the left side.(Pic.32,Table No.5)

2. The distance of the inferior epigastric artery from midline from a point midway between the umbilicus and the pubic symphysis ranged between a minimum of 3.1 cm to a maximum distance of 4.2 cm on the right side. The minimum distance was 3 cm and the maximum distance 4.1 cm on the left side. Mean±SD was 3.5±0.4 cm on the right side and 3.4±0.3 cm on the left side.(Pic.34,Table No.6)

3. The distance of the inferior epigastric artery at its origin from midline just above pubic symphysis ranged between a minimum value of 3.5cm to a maximum value of 7.8 cm on the right side, and on the left side, the minimum value was 3.8 cm and the maximum was 8 cm. Mean±SD was 5.7±1.1 cm on the right side and 6.2±1.3 cm on the left side.(Pic.33,Table No.7)

Among the three levels the minimum distance was 3 cm and maximum distance was 8 cm.

4. The distance from the insertion of rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin varied from a minimum distance of 3.4 cm and a maximum distance of 6.7 cm on the right, and minimum distance of 4.1 cm and a maximum distance of 7 cm on the left side. Mean±SD was 5±1.2 cm.(Pic.35,Table No.8)

In the 6 **foetal specimens**

1. The distance of the inferior epigastric artery from the midline at the level of the umbilicus was an average of 1.4cm.

2. The distance of the inferior epigastric artery from midline from a point midway between the umbilicus and the pubic symphysis was an average of 1.2cm.

3. The distance of the inferior epigastric artery at its origin from midline just above the pubic symphysis was an average of 2cm.

4. The average distance from the insertion of rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin was 1.5cm.

IX. Length of the inferior epigastric artery

Two lengths were measured in all specimens.

One length a) was taken from its point of origin to its entrance into the rectus sheath. This length varied from 3 cm to 7.2 cm on the right side , and a 3.2 cm to 7.4 cm on the left. The Mean$\pm$SD was 5.78$\pm$0.9 cm. (Pic.36,Table No.9).

The second length (b) was measured from the point of origin of the inferior epigastric artery to its entrance into the rectus muscle substance. (Pic.37, Table No.10).

This value ranged from 4 cm to 15 cm on the right side, and 4.3cm to 14 cm on the left side. The Mean$\pm$SD was 10.4$\pm$2.6 cm.

The length of the inferior epigastric artery in the 6 **foetal specimens** at the entry into the posterior rectus sheath was on an average 1.5 cm. The second length measured from the origin of the inferior epigastric artery to its entrance into the rectus muscle substance was an average of 4.1 cm.

X. Diameter of the inferior epigastric artery

The diameter was measured in 64 slice CT angiograms. 8 lower limb and 2 abdominal angiograms done for various reasons in patients in the age group of 15-90 yrs were selected and the diameter of the inferior epigastric artery was measured at its origin and at its entrance into the rectus muscle.(Pic.38,39).

The diameter at the origin of the artery was in the range of 2.6mm to 3.2 mm. Average was 2.8 mm. Mean $\pm$ SD =2.8$\pm$0.2mm (Table No.11).

The diameter at the entrance of the inferior epigastric artery into the rectus muscle was in the range of 1.7 to 2.3mm. The mean diameter was 2mm. Mean $\pm$ SD=2$\pm$0.1mm.(Table No.12).

In one CT picture, the inferior epigastric artery showed a double stem before entering the rectus muscle.The diameters were 1.8mm and 1.9mm.(Pic.40)

Radiological Study

Adult routine clinical angiogram study

10 adult abdominal angiograms taken for various reasons were studied for the inferior epigastric artery. The inferior epigastric artery origin was seen from the external iliac artery in all the 10 cases. The whole course could not be studied because of the overlapping of the other arteries of the abdominal cavity. (Pic.42).

Adult cadaveric abdominal wall angiogram

In the all the three cadaveric angiograms, the origin of the inferior epigastric artery was seen from the external iliac artery. A cremasteric and a pubic branch were visible on the left side (Pic.41).

The inferior epigastric artery had a double stem before entering the rectus muscle on both sides. Both the stems divided into many medial and lateral branches. There were many muscular branches on the lateral side and a few medial branches. Finally the inferior epigastric arteries divided into numerous terminal branches above the level of the umbilicus.

Adult 64 slice CT angiogram

In the 10 CT images selected, the inferior epigastric artery arose from the external iliac artery. In one CT image, the inferior epigastric artery had a double stem before entering the rectus muscle substance. The terminal branches and muscular branches were seen. (Pic.43,44,45)

Histological study

Histological study of inferior epigastric artery and internal thoracic artery was done.

In the **inferior epigastric artery** the intima showed flattened endothelial cells. The endothelial cells seemed to lie directly on the internal elastic lamina. The tunica media consisted of almost entirely smooth muscle fibres. The combined thickness of the tunica intima and the tunica media was thinner than the internal thoracic artery. The tunica adventitia was thick. (Pic.46,48).

In the **internal thoracic artery** the intima was thicker than inferior epigastric artery. The tunica media consisted of predominantly elastic fibres. The combined thickness of intima and media was higher than inferior epigastric artery. (Pic.47,49)

DISCUSSION

The study of the inferior epigastric artery was undertaken to study the mode of origin, the course, branches and anastomoses of the inferior epigastric artery . Measurements were taken from the midline to the inferior epigastric artery, at different levels. This should provide a guideline to the surgeons to perform a safe surgery stearing clear of the inferior epigastric artery. The length of the inferior epigastric artery has been taken at two levels and the diameter also at two levels. The plastic surgeons using the inferior epigastric artery as the pedicle would benefit from the detailed study done on the inferior epigastric artery under the 10 parameters.

I **Dissection study**

Origin of the inferior epigastric artery

a) From the external iliac artery

Henry Gray (1858),Morris (1893), D.J.Cunningham (1902),R.J.Last (1954) have quoted that the inferior epigastric artery arises from the external iliac artery.

Sir John Bruce,R.Walmsley,J.A.Ross(1964), Giovanni Teodori et al (1984), George C. Cormack and B.George H.Lamberty(1986) and **Michael S. Baggish** and **Mickey M. Karram(2001) and Levent Sarikcioglu et al(2003**) have also quoted that the inferior epigastric artery takes its origin from the external iliac artery.

In the **present study**, the inferior epigastric artery was found to arise from the external iliac artery in all the 50 adult and 6 foetal specimens conforming to the statement of the above authors.

A.M.Buchanan(1906) said that the inferior epigastric artery arises from the medial side of the external iliac artery.

Donald Serafin(1996) stated that the deep inferior epigastric artery arises from the medial aspect of the inferior epigastric artery.

Thomas Dwght et al (1907) have said that the inferior epigastric artery arises from the anterior surface of the external iliac artery.

But in the **present study**, in all the 50 adult specimens and 6 foetal specimens, the origin of inferior epigastric artery was from the anteromedial surface of the external iliac artery.

b) from any other source of origin

Adachi (1928) described the arterial variation in which the inferior epigastric artery and obturator arteries arose as a common trunk from the medial circumflex femoral artery.

Bergman et al (1984) have noted that the common origin for the inferior epigastric artery and the obturator artery occurs in 20-30%,and **Jakubowicz M.Czarniawska-Grzesinska M (1996**) in 4%.

Emura et al (1989) have reported a trunk for the medial circumflex femoral, inferior epigastric artery and obturator arteries arising from the femoral artery in one case.

J.R.Sanudo et al (1993) have described two cases of arterial variation in which the obturator, inferior epigastric and medial circumflex femoral arteries arose from a common trunk from the external iliac artery.

Bilgic S.Sahin B (1997) reported a common trunk for the obturator, inferior epigastric and deep femoral arteries arising from the external iliac artery.

C.Kopuz et al (2000) reported a case in which the inferior epigastric artery arose from a common trunk with the medial circumflex femoral artery. The common trunk arose from the femoral artery.

The inferior epigastric artery arose as a separate trunk from the external iliac artery in all the 50 adult specimens and 6 foetal specimens in the **present study**. No common trunk of origin with the obturator artery, medial circumflex femoral artery or deep femoral artery was found in the **present study.**

Dschau (1936) reported a case in which the inferior epigastric artery and obturator arise from the medial circumflex femoral artery as independent arteries.

Giovanni Teodori et al (1984) said that the inferior epigastric artery may arise below the inguinal ligament, from the femoral or from the deep femoral. Sometimes it arises from the obturator artery, the latter vessel being furnished by the internal iliac, or the epigastric may be formed by two branches, one from the external iliac, the other from the internal iliac.

Donal Shanahan and R.K.Jordan (1997) have shown that the inferior epigastric artery was a recurrent branch of an anomalous medial circumflex femoral artery arising from the external iliac artery in one case.

Levent Sarikcioglu &Muzaffer Sindel (2001) have described a vessel variation in a 55yr old male cadaver in which the obturator artery had its origin from the external iliac artery and the inferior epigastric artery had its origin from the femoral artery.

Ercan Tanyeli et al (2006) found the inferior epigastric and the external pudendal arteries arising from the deep femoral artery.

The origin of inferior epigastric artery from the femoral, deep femoral or medial circumflex femoral artery or obturator artery was not observed in any of the adult or foetal specimens in the **present study**.

The inferior epigastric artery was not formed by two branches, one from the external iliac and the other from the internal iliac in any of the 50 adult specimens or 6 **foetal specimens** in **present study.**

c) Site of origin of the inferior epigastric artery in relation to the inguinal ligament

Henry Gray (1858) quoted that the inferior epigastric artery aises from the external iliac artery posterior to the inguinal ligament.

R.J.Last (1954) said that the inferior epigastric artery leaves the external iliac artery at the inguinal ligament.

In the **present study,** 23 adult specimens (46%) showed the inferior epigastric artery arising at the level of the inguinal ligament as described by the above authors. In 4 **foetal specimens**, the inferior epigastric artery arose at the level of the inguinal ligament.

Morris (1893) and **John E. Skandalakis(2004)** have stated that the inferior epigastric artery arises just above the inguinal ligament.

A.M.Buchanan (1906) said that the inferior epigastric artery arises ¼ inch above the inguinal ligament.

Thomas Dwght et al(1907) quoted that the inferior epigastric artery may arise from the external iliac artery higher up than usual as high as 6 cm (2 3/8 inch) above the inguinal ligament.

Sir John Bruce,R.Walmsley,J.A.Ross(1964) said that the inferior epigastric artery arises from the external iliac artery about 0.5cm above the inguinal ligament.

Giovanni Teodori et al (1984) stated that the origin of the epigastric may take place from any part of the external iliac artery between Poupart`s ligament and 2 inches and a half above it.

Donald Serafin (1996) noted that the deep inferior epigastric artery arises from the medial aspect of the external iliac artery, opposite the origin of the deep circumflex iliac artery approximately 1 cm above the inguinal ligament.

Michael S.Baggish and Mickey M. Karram (2001) noted that the inferior epigastric artery takes its origin from external iliac vessels at a point cranial to the inguinal ligament.

Levent Sarikcioglu et al (2003) reported that the inferior epigastric artery arose 1.2 -2.8 cm above the inguinal ligament.

In the **present study** the inferior epigastric artery was observed to arise above the inguinal ligament in 27 adult cases (54%). The distance of the inferior epigastric artery from the inguinal ligament was between 0.5-2cm, average 1.1cm, which coincides with the reports of **A.M.Buchanan, Sir John Bruce et al, Donald Serafin,** and **Michael S. Baggish & Mickey M. Karram.** (Chart 1D).

In 2 **foetal specimens** the inferior epigastric artery arose 0.4cm above the inguinal ligament. Foetal study has not been mentioned by any of the authors.

II. Level of entry into the rectus muscle substance- upper, middle, or lower third

W.Henry Hollinshead (1956) said that the superior and the inferior epigastric vessels usually lie at first on the posterior surface of the rectus muscle and the inferior epigastric artery tends to enter the middle third of the muscle.

Frank J. Milloy, Barry J. Anson and David K. McAfee (1960) in a study of 115 cadavers found that the inferior epigastric artery enters the rectus muscle substance in the middle third 126 times (78 percent).

In the **present study** the inferior epigastric artery was seen to enter the rectus muscle in the middle third in 36 cases (72 percent) which is lower than the percentage mentioned by Milloy et al.

Frank J. Milloy, Barry J. Anson and David K. McAfee (1960) in the study of 115 cadavers found that the inferior epigastric artery enters the rectus muscle substance in the lower third 28 times (17 percent) and in the and upper third 8 times (5 percent).

In the **present study** the inferior epigastric artery was seen to enter the rectus muscle in the lower third in 10 cases (20 percent) and in the upper third in 4 cases (8 percent) which is closer to the findings of Milloy et al.(Chart 2D).

In all the 6 **foetal specimens**, the inferior epigastric artery entered the middle third of the rectus abdominis. The above authors have not mentioned a study on foetuses.

III Single or double main stem of the inferior epigastric artery before entering the rectus muscle substance

Frank J. Milloy, Barry J. Anson and David K. McAfee (1960) in a study of 115 cadavers, found the inferior epigastric artery to consist of a single main stem in 139 (86%) instances and of a double main stem in 23 (14%) instances before entering the muscle substance.

The **present study** of 50 adult cadaveric halves showed the inferior epigastric artery having a single main stem in 43 instances (86%) and a double main stem in 7 specimens (14%) which is perfectly congruent with the author`s findings.

In all the 6 **foetal specimens**, the inferior epigastric artery had a single stem before entering the rectus abdominis.

IV. Branches of the inferior epigastric artery

Henry Gray (1858), D.J.Cunningham(1902) and Thomas Dwght(1907) have said that the inferior epigastric artery has the following branches, the cremasteric artery, a pubic branch, muscular and cutaneous branches.

Morris(1893) stated that the branches of the inferior epigastric artery are small and include a) the external spermatic artery(a.spermatica externa) or the artery of the round ligament of uterus (a.ligamentum teres uteri) and b) the pubic branch.

A.M.Buchanan(1906) said that the inferior epigastric artery branches are cremasteric, pubic, muscular, cutaneous, peritoneal and terminal or anastomotic.

Russel T.Woodburne(1957) described that several small branches of the inferior epigastric artery arise near its origin. He also mentions the cremasteric branch and pubic branch.

In the **present study** of 50 adult specimens, the inferior epigastric artery branches were the cremasteric, pubic, muscular, cutaneous, peritoneal and anastomotic which coincides with Buchanan.

In the **foetal specimens**, cremasteric branch, pubic branch and muscular branches were only traceable.

V. Abnormal obturator artery

Henry Gray (1858) D.J.Cunningham (1902) have mentioned that the pubic branch of the inferior epigastric artery may be enlarged to form the abnormal obturator artery.

W.Henry Hollinshead (1956), J.D.Boyd, W.J.Hamilton et al (1956) and Russel T. Woodburne(1957) noted that the pubic branch may be enlarged to form the abnormal obturator artery.

R.D.Lockhart,G.F.Hamilton and F.W.Fyfe(1959),Harold Ellis(1960) and Sir Solly Zuckerman(1961) have described that the pubic branch of inferior epigastric artery may replace the obturator artery, as the abnormal obturator artery.

In the **present study** of 50 adult cadaveric halves, the pubic branch of inferior epigastric artery was enlarged in 8 specimens which replaced the obturator artery and passed through the obturator canal as the abnormal obturator artery.

The percentage frequency of the abnormal obturator artery given by other authors are **Pfitzner 30.4%,Jastchinski 60%,Morris 37%,Parsons & Keith 8%,Thomas Dwght et al 30%, J.C.B.Grant 33%, Arthur Curtis,Barry J Anson et al 25%,J.L.Braithwaithe 19.5%,R.J.Last 50%,Robert F Muller &Melvin M Figley 37%,A Lee McGregor 30%,Page & Patrick 30% and Suppa ut Pungpapong & SathonThum-Umnauysuk 13.6%.**

In the **present study** the pubic branch of inferior epigastric artery was enlarged , which replaced the obturator artery as abnormal obturator artery. The percentage frequency of occurrence of the abnormal obturator artery in the present study is 16% which is nearest to the values of **J.L.Braithwaite, and Suppa ut Pungapong and SathonThum-Umnauysuk**.(Chart 4D).

Henry Gray (1858) said that the abnormal obturator artery lies close to the medial border of the femoral ring.

Morris (1893), R.J.Last(1954), Russel T.Woodburne(1957), have stated that the abnormal obturator artery may lie on the medial border of the femoral ring.

R.D.Lockhart,G.F.Hamilton and F.W.Fyfe(1959),Harold Ellis(1960) said that the abnormal obturator artery is related to the medial border of the femoral ring.

Ernest Gardner Donald J.Gray and Ronan O 'Rahilly(1960) and John E.Skandalakis &Stephen W.Gray(1974) noted that the abnormal obturator artery coursed along the medial border of the femoral ring.

According to **D.J.Cunningham(1902),** the abnormal obturator artery related to the medial border of the femoral ring is 30%, according to **Thomas Dwght et al(1907**) 17.5%, and according to **A Lee McGregor(1975) 10%.**

In the **present study** of 50 adult cadaveric halves, in 12.5% cases, the abnormal obturator artery was related to the medial border of the femoral ring which is closest to the values of **A Lee McGregor.**

Morris (1893), R.J.Last (1954), Russel T.Woodburne (1957), have stated that the abnormal obturator artery may lie on the lateral border of the femoral ring.

R.D.Lockhart, G.F.Hamilton and F.W.Fyfe (1959), Harold Ellis(1960) said that the abnormal obturator artery is related to the lateral border of the femoral ring.

Ernest Gardner Donald J.Gray and Ronan O 'Rahilly(1960) and John E.Skandalakis &Stephen W.Gray(1974) noted that the abnormal obturator artery coursed along the lateral border of the femoral ring.

D.J.Cunningham(1902) stated that the abnormal obturator artery descends on the lateral side of the femoral ring in 70% cases and **Thomas Dwght et al (1907)** has described the abnormal obturator artery along the lateral border of the femoral ring in 60% of cases.

A Lee McGregor (1975) said that the abnormal obturator artery may stick to the side of the femoral vein (lateral border of femoral ring) in 90% of cases.

In the **present study,** in 87.5% of cases the abnormal obturator artery descended on the lateral border of the femoral ring similar to the findings of **A Lee McGregor(1975).** (Chart 3D).

Thomas Dwght et al (1907) said that the abnormal obturator artery descended across the femoral ring in 22.5% cases.

None of the 50 adult specimens in the **present study** showed the abnormal obturator artery lying across the femoral ring.

Suppa ut Pungapong and SathonThum-Umnauysuk (2005) found the abnormal obturator artery in 21.2% males (7/33) and in 5.5% females (2/33).

The incidence of abnormal obturator artery in males was 32% (5/25) and 12% (3/25) in females in the **present study** of 50 adult specimens. This does not coincide with the report of **Suppa ut Pungapong and SathonThum-Umnauysuk**.(Chart 5D).

Of the 6 **foetal specimens**, in one specimen abnormal obturator artery was seen. It descended on the lateral border of the femoral ring. None of the authors have mentioned a foetal study.

VI. Pattern of anastomoses of the inferior epigastric artery with the superior epigastric artery

Frank J.Milloy,Barry J.Anson and David K.McAfee(1960) in a study of 115 cadavers have mentioned gross anastomoses of the superior and the inferior epigastric arteries in 40%.

In the **present study**, gross anastomoses was found in 14 adult specimens (28%) and no anastomoses was found in 36 specimens(72%).

Milloy et al(1960) mentioned 1 anastomosis between the superior epigastric artery and the inferior epigastric artery in 18.3% cases.

Moon H.K.&Taylor G.I (1988) in a radiographic study, found a pattern of Type I similar to 1 anastomosis 29%

1 anastomosis mentioned by Moon & Taylor as Type I was observed in 16% of cases in the **present study** which is similar to Milloy et al but lower than Moon &Taylor study.

Milloy et al noted 2 anastomoses between the superior and inferior epigastric arteries in 18.3% cases and **Moon & Taylor** found a pattern of Type II similar to 2 anastomoses in 57% cases.

In the **present study**, 2 anastomoses was found in 10% specimens, which is lower than **Milloy et al** study and much lower than **Moon & Taylor** study.(Chart 6D)

Milloy et al found multiple anastomoses 3.3% and **Moon & Taylor** in 14%.

In the **present study** of 50 adult specimens, multiple anastomoses was present in 2% specimens which is similar to the finding of **Milloy et al**.

In all the **6 foetal specimens**, no anastmoses was seen between the inferior epigastric artery and the superior epigastric artery. Foetal study has not been mentioned by the above authors.

VII. Level of anastomoses – at or above the level of the umbilicus

A.M.Buchanan(1906) and Frank J. milloy,Barry J.Anson and David K.McAfee(1960) have stated that the inferior epigastric artery and superior epigastric anastomose above the level of the umbilicus.

Berish Strauch,HanLiang et al (1993),D.M.O`Dey et al(2004) and Boyd J.B.Taylor G I,Corlett R.(2002) have mentioned the anastomoses within the rectus muscle above the level of the umbilicus.

George C.Cormack and B.George H.Lamberty(1986),Geovanni Teodori et al(1984) have described the anastomoses between inferior epigastric artery and the superior epigastric artery above the level of umbilicus.

Donald Serafin(1996) and Gagnon,A.R,Glondeel,P.N(2006) have observed the anastomoses between inferior epigastric artery and the superior epigastric artery occurring in the watershed within the rectus abdominis muscle midway between the xiphoid process and the umbilicus.

In the **present study** of 50 adult cadaveric halves, in all the 14 adult specimens in which anastomoses was seen, the level of anastomoses was above the umbilicus which conforms to the observations of all the above authors.

W.Henry Hollinshead(1956) noted that the terminal branches of the inferior epigastric artery and the superior epigastric artery anastomose in the rectus muscle at about the level of the umbilicus.

In none of the adult specimens in the **present study** anastomoses at about the level of umbilicus was found.

In all the 6 **foetal specimens** there was no anastomoses between the superior and inferior epigastric arteries. Foetal study has not been mentioned by any of the authors.

VIII. Distance of the inferior epigastric artery from the important landmarks of the abdomen and pelvis

TeLinde Richard W (1894) stated that at the level of the umbilicus the inferior epigastric artery is 4.5 cm from the midline.

Alan A.Saber et al(2004) in a study of abdominal and pelvic CT images of 100 patients found that the average distance of the inferior epigastric artery from the midline at the umbilicus was 5.88 cm on the right and 5.55 cm on the left.

In the **present study** of 50 adult specimens the **distance of the inferior epigastric artery from the midline at the level of the umbilicus** was 3.5±0.4 cm on the right and 3.4±0.3 cm on the left, which is closer to the values of **TeLinde Richard W.**

Alan A.Saber et al (2004) found that the average distance of the inferior epigastric artery at the level midway between the umbilicus and the pubic symphysis was 5.32cm on the right and 5.25cm on the left.

In the **present study** of 50 adult cadaveric halves, the **distance of the inferior epigastric artery from the midline at the level midway between the umbilicus and the pubic symphysis** was 3.6±0.2 cm on the right and 3.5±0.2 cm on the left, which does not concur with the author. (Table No.1D)

Michael S.Baggish and Mickey M.Karram(2001) quoted that the distance from the midline (above the upper margin of the symphysis pubis) to the inferior epigastric vessels is 6 – 7 cm.

Alan A.Saber et al(2004) found that the average distance of the inferior epigastric artery from the midline at the level just above the pubic symphysis was 7.47 cm and 7.49cm respectively on the right side and the left side.

In the **present study** of 50 adult specimens, **the distance of the inferior epigastric artery from the midline at the level just above the pubic symphysis** was 5.7±1.1 cm on the right side and 6.2±1.3 cm on the left side, which is similar to **Michael S.Baggish and Mickey M.Karram(2001)** values.

A.M.Buchanan(1906) proclaimed that the first part of the medial border of the deep inguinal ring to the lateral border of the rectus abdominis at a point about midway between the umbilicus and the superior border of the pubic symphysis. The course of the second part (vertical) of the vessel is represented by a line corresponding with the centre of the rectus and about 1 ½ inches from the linea alba.

J.C.B.Grant (1937) specified that the lateral border of the rectus is a nearly bloodless line, because very few branches of the epigastric arteries cross it and anastomose with the intercostals and lumbar arteries.

Hurd,William et al(1994) testified that the inferior epigastric artery was 5.6±1.0 cm from the midline.

In the **present study** of 50 adult specimens, the distance of the inferior epigastric artery from the midline ranged between 3 -8 cm similar to the above authors.

Frank J.Milloy,Barry J.Anson &David K McAfee(1960) measured the distance from the insertion of the rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin – the medial side of Hesselbach`s triangle and found it to be 2-10cm.

In the **present study** of 50 adult specimens**,** the distance between the rectus tendon insertion and the intersection of the inferior epigastric artery into the lateral rectus margin was 5±1.2 cm which concurs with **Milloy et al** study.

In the 6 **foetal specimens**, the average of the inferior epigastric artery from the midline at the level of umbilicus was 1.4cm.

The average distance of the inferior epigastric artery from the midline at the level midway between the umbilicus and the pubic symphysis was 1.2 cm .

The average distance of the inferior epigastric artery from the midline at a level just above the pubic symphysis was 2 cm.

The average distance from the insertion of the rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin was 1.5 cm.

IX. Length of the inferior epigastric artery

Two lengths have been taken in the **present study**. One from the point of origin of the inferior epigastric artery to its entrance into the rectus sheath. The second length was from the point of origin to its entrance into the rectus muscle.

Donald Serafin(1996) noted that from its point of origin to its entrance into the rectus sheath, the inferior epigastric artery length is 7.6cm and **Kim D I** gave this length as 4cm.

In the **present study** the length of the inferior epigastric artery from the point of its origin to its entrance into the rectus sheath was found to be 5.8±0.9 cm which is close to **Kim D I** et al values.(Chart 7D)

Berish Strauch, Han-Liang et al(1993) stated that the average length of the inferior epigastric artery from its origin to its entrance to the rectus muscle is 10.9cm(7.1 to 14.7cm).

In the **present study** the length of the inferior epigastric artery from its point of origin to its entrance into the rectus muscle substance was 10.4±2.6cm similar to the authors' observations.(Chart 8D)

E.Migalter et al(1992) evaluated the usable length of the inferior epigastric artery for coronary artery bypass grafting and found the usable length to be 6 to 16 cm.(mean±SD=11±0.25cm)

Watanabe et al(1994) noted that the mean length of the inferior epigastric artery for CABG is 12.2cm (7.5 -17cm).

Gagnon A R, Blondeell,PN(2006) has found the usable length of inferior epigastric artery as 10 cm to 18 cm for musculocutaneous flaps.

From the **present study** of 50 adult specimens it is evident that the average length of the inferior epigastric artery is 10.4 cm which can be used in CABG and flap surgery similar to the findings of the above authors.

In the 6 **foetal specimens**, the average length of the inferior epigastric artery from its origin to the lateral rectus muscle margin was 1.5cm and the length from its origin to the entry of the inferior epigastric artery into the rectus abdominis was 4.1cm.

X. Diameter of the inferior epigastric artery

The diameter of the inferior epigastric artery at its origin specified by **Berish Strauch** et al(1993) is 2.7 mm(range 1.6 -3.5 mm),**Donald Serafin(1996)** 3.4mm,**Gagnon A R,Blondeel P N(2006)** 3 -3.5mm and **E.Migalter et al** (1992) 2.5 -3.5mm.

The diameter of the inferior epigastric artery at its point of origin in the **present study** was 2.8$\pm$0.2mm. This value coincides with the statement of **Berish Strauch** et al.(Chart 9D)

The distal diameter or diameter of the inferior epigastric artery at its entrance into the rectus muscle noted by **Berish Strauch et al(1993)** is 2.0mm(1.5 -2.6mm) and **E.Migalter et al(1992**) 2 -3mm.

The diameter of the inferior epigastric artery at its entrance into the rectus muscle substance in the **present study** was 2$\pm$0.1 mm.This value also coincides with the readings of **Berish Strauch** et al.

John E. Skandalakis(2004) noted that the average diameter of the inferior epigastric artery is 3.4mm.

Kim D I et al(2003) found the external diameter of the inferior epigastric artery to be 2.6$\pm$0.6mm.

In the **present study** of 50 adult cadaveric halves, the average diameter of the inferior epigastric artery was 2.4mm, which is similar to the value of **Kim D I et al(2003).**

Histology

Giovanni Teodori et al (1984) said that the intima of inferior epigastric artery was less thin than internal thoracic artery.

A.Wahba et al(1994) said that the inferior epigastric artery showed a lower degree of intimal thickening than internal thoracic artery.

In the **present study**, the intima of the inferior epigastric artery was thinner than the internal thoracic artery conforming to the **A.Wahba et al (1994)** findings.

Giovanni Teodori et al stated the combined thickness of media and intima is lower in the inferior epigastric artery than internal thoracic artery.

In the **present study**, the combined thickness of the media and intima was lower in inferior epigastric artery than internal thoracic artery concurring with the author's findings.

A.Wahba et al (1994) stated that the internal thoracic artery resembled an elastic artery and that the inferior epigastric artery resembled a muscular artery.

In the **present study**, the histology of the internal thoracic artery showed that it contained more elastic fibres whereas the inferior epigastric artery had mainly smooth muscle fibres in the media similar to **A.Wahba et al** statement.

CONCLUSION

The inferior epigastric artery, the most important and largest blood vessel of the anterior abdominal wall, was studied in detail by conventional dissection, predissectional dye injection, angiographic and histological studies.

The observations of the study have been correlated with the findings of already existing studies. The following conclusions are derived from the study.

- The origin of the inferior epigastric artery is from the anteromedial surface of the external iliac artery bilaterally at or just above the inguinal ligament.

- The inferior epigastric artery ascends between the rectus abdominis muscle and its sheath for a considerable distance before entering the rectus muscle in its middle third in 72%, lower third 20% and upper third 8%.

- Commonly the inferior epigastric artery has a single stem (86%), but double stem before entering the rectus muscle substance occurs in 14%.

- Abnormal obturator artery is found in 16%.

- In 87.5%, the abnormal obturator artery is related to the lateral border of the femoral ring, and in 12.5% it descends along the medial border of the femoral ring.

- The pubic branch of the inferior epigastric artery crosses the superior pubic ramus to anastomose with the pubic ramus of the obturator

artery(corona mortis) where it is prone to injury in operations around the retropubic area like laparoscopic hernia repair and laparoscopic prostatectomy.

- Gross anastomoses between the superior and inferior epigastric arteries is observed in 28%, and it occurs above the level of the umbilicus, whereas no anastomoses is observed in 72%.

- In cases with anastomoses, Type I pattern (Moon & Taylor) is 16%, Type II 10% and Type III 2%.

- The average length of the inferior epigastric artery from the origin to the lateral rectus margin is 5.8 cm and from the origin to the entry into the rectus muscle substance is 10.4 cm.

- The diameter of the inferior epigastric artery observed by 64 slice CT angiographic study is 2.8 mm at the origin, and 2 mm at its entrance into the rectus abdominis.

- The distance of the inferior epigastric artery from the midline at various levels have been noted. Regardless of the abdominal level, the dangerous zone is found to be between 3 cm and 8 cm from the midline. Staying away from this area either medially or laterally will determine the safety zone of entry into the abdominal wall without risk of injury to the epigastric vessels.

- The combined thickness of the intima and media is lower in inferior epigastric artery than the internal thoracic artery.

- The media of the inferior epigastric artery consists of thickly packed smooth muscle fibres whereas in the internal thoracic artery, the media contains mainly elastic fibres.

A comprehensive study of the origin, course, branches, anastomosis, length, diameter and distance of the inferior epigastric artery from important landmarks of the abdominal wall under a common umbrella will prove to be useful to the plastic surgeons who consider the lower abdomen skin and fat to be an ideal material for breast reconstruction, cardiothoracic surgeons evaluating the inferior epigastric artery as an alternative conduit for coronary artery bypass grafting, the laparoscopic surgeons and the general surgeons.

BIBLIOGRAPHY

1. Adachi B(1928) Das Arteriensystem der Japana,Kyoto B H supp to Acta Scholae Medicinalis Universitatis Imperalis in Kioto, 9(1926-7)

2. Alan A Saber,Ali M Meslemani,Robert Davis,Ronald Pimentis(2004) Safety zones for Anterior Abdominal wall Entry during Laparoscopy-A CT scan Mapping of Epigastric vessels. Annals of Surgery Vol 239 No.2 Feb 2004:182-185

3. Arey L B(1963) The development of peripheral blood vessels. In the peripheral blood vessels(ed.J.L Orbison &D E Smith)pp1-16 Baltimore:Williams and Wilkins

4. Arthur H Curtis, Barry J Anson, Franklin L Ashley & Tom Jones Surgery, Gynaecology and Obstetrics Vol 75,July 1942,P -423

5. Bergman R A,Thompson S A,Afifi A K(1984)Catolog of Human variation,pp 124-125.Baltimore: Urban &Schwarzenberg

6. Berish Strauch,Han Liang Yu, Zhong-weichen,Ralph Liebling(1993) Atlas of microvascular surgery P-448-449

7. Bilgic S,Sahin B(1997) Rare arterial variation; a common trunk from the external iliac artery for the obturator, inferior epigastric and profunda femoris arteries SurgRadiol.Anat,19;45-47

8. Boileau Grant J.C (1937) A Method of Anatomy - Sixth edition P211,212,357

9. Boyd J B,Taylor G I,Cirlett R(2002) The vascular territories of the superior epigastric and the deep inferior epigastric systems. Plastic ReconstructiveSurg2002.Feb;109(2):539-43;discussion 544-7

10. Boyd J D,Sir Wilfred E Legros Clark,W J Hamilton,J M Yoffey, Sir Solly. Zuckerman,A B Appleton (1956) Textbook of Human Anatomy P - 363

11. Braithwaite (1952) Variations in origin of the parietal branches of the internal iliac artery Journal of Anatomy Vol 86,Jan-Oct 1952,P – 423-429

12. Buchanan A. M (1906) Manual of Anatomy –Eighth edition P -729,730

13. Cunningham D.J (1902) Textbook of Anatomy –Tenth edition P –904

14. D M O'Dey D M,Heimburg D V,Prescher and Pallua N(2004) The arterialvascularisation of the abdominal wall with special regard to the umbilicus. Acta Orthop Scand.2004Feb;75(1):53-5

15. Donal Shanahan and Jordan R K(1997) Rare origin of the inferior epigastric artery from an anomalous medial circumflex femoral artery J of Anat(1997)191;P611-613

16. Donald Serafin(1996)Atlas of microsurgical composite tissue transplantation P-227 -247

17. Dschau V F(1936/37) Einebisher unbekannte Varietat der Arteria Obturatoria und pudenda accesoria mt einter varietat der Arteria circumflexa femoris medialis. Anatomischer Anzeiger 83,25-29

18. Emura S,Shoumura S,Ishizaki N,Yamahira T,Ito M, Chen J Y,Isono H(1989) The anatomical study on the branches of the femoral artery.Kaibogaku Zasshi,64;196-205

19. Ercan Tanyeli,Mehmet Yildrim,Mehmet Uzel and Feridun Vural(2006) Deep femoral artery with four variations: a case report. Surgical and Radiologic Anatomy Vol28,No:2/May 2006

20. Ernest Gardner,Donald J Gray,Ronan O'Rahilly (196) Anatomy 2nd edition P –471

21. Frank J Milloy,Barry J Anson and David K McAfee (1960) Surgery,Gynaecology & artery Journal of Anatomy Vol 86,Jan-Oct 1952,P – 423-429.

22. Gagnon A R,Blondeell P N(2006) Deep and superficial inferior epigastric artery perforator flaps. Cirugia Plastica Ibere-Latinoamericana-Vol 32 No.4 de 2006,P 7-13

23. George C Cormack & B.George H.Lamberty (1986) The Arterial Anatomy of skin flaps First edition P – 150 – 153

24. Giovanni Teodori,Philippe-PrimoCatmmi,Thomas Toscano and Massimo Bernardi (1984) Plastic Reconstructive Surgery 1984 Jan;73(1) 1-16. Use of inferior epigastric artery for CABG.

25. Harold Ellis (1960) Clinical Anatomy Seventh edition P -287,288

26. Henry Gray (1858)Gray's Anatomy– 39'th edition P –1101

27. Henry Hollinshead W (1956) Anatomy for Surgeons Vol 2,2nd edition, P - 235, 263

28. HurdWilliam W,Bude ,Ronald O,De Lancey,John O L;Newman,Joel S(1994) The location of Abdominal wall blood vessels in relationship to abdominal landmarks apparent at laparoscopy. American J of Obstetrics and Gynaec1994,171:642 - 6

29. Jakubowicz M Czarniawska –Grzesinska M(1996) Variability in origin andtopography of the inferior epigastric and obturator arteries. Folia Morphol (Warsz)55:121-126

30. Jastschinski S N(1891) Die Abweichungen der Arteria obturatoria nebst Erklarung ihres Entstehens. Monatsschrift fur Anatomie und Physiologie 8, 367 -386

31. John E Skandalakis(2004) Skandalakis'Surgical Anatomy P-408-438

32. John E Skandalakis,Stephen W Gray and John T Akin Jr (1974) The Surgical Anatomy of Hernial rings, The Surgical clinics of North America Vol 54, No.6, Dec. 1974,P –1230.

33. Kim D I,Lee U Y,Han S H,Paik D J,Koh K S, Chung R H Lee P K,Rhie J W, Ahn S A,Tekdemir(2001) Corona mortis:an anatomic study in seven cadavers and anPhys Anthropol 2003 Sep;16(3):137-145

34. Kopuz C,M Yildrim,A Ozturk,Z Malazgirt(2000) Rare origin of the inferior epigastric and medial circumflex femoral arteries arising from a common trunk. Europeon J ofPlastic Surgeons Vol 23 No.3 Dec 2000

35. Last R.J (1954) Last's Anatomy – Ninth edition P -300

36. Lee McGregor A (1975) A synopsis of surgical anatomy Eleventh edition P – 101

37. Levent Sarikcioglu,Muraffer Sindel(2001) Multiple vessel variations in the retropubic region .Folia Morphologica Vol 21 No.1 P-43 -45(2001)

38. LeventSarikcioglu,Muzaffer Sindel,Feyyaz Akyildiz,Semih Gur(2003) Anastomotic vessels in the retropubic region:Corona mortis Folia Morphol.Vol 62,No.3 P-179-182

39. Lockhart,G F Hamilton and F. W.Fyfe (1959) Anatomy of the human body P – 628.

40. Michael S Baggish,Mickey M.Karram(2001) Atlas of Pelvic Anatomy and Gynaecologic Sugery Second edition P 71-75

41. Migalter E, Pearl J M,Laks H,Elami A,Lowie H W, Baker E D and Buckberg G D (1992). The inferior epigastric arteries as coronary bypass conduits. The Journal of Thoracic and Cardiovascular Surgery, Vol 103,463 -465,1992

42. Moon HK,Taylor GI (1988) The vascular anatomy of rectus abdominis, musculocutaneous flaps based on the deep superior epigastric system.Plast.Reconstr Surg.1988 Nov;82(5) :815 -32.

43. Page. B & Patrick (2003) Laparoscopic hernia Surgery. First edition P – 42.

44. Parsons FG &A Keith (1897) Sixth annual report of the Committee of Collective investigation of the Anatomical Society of Great Britain and Ireland, 1895 – 96 J.Anat.Physiol,London 31:31-44

45. Pfitzner,W (1889) uber die Ursprungsverhaltnisseder Arteria obturatoria.Anat Anz.4:504-514

46. Robert F Muller and Melvin m Figley (1957) The American Journal of Roentgenology Vol.77, Jan. Jun. 1957 P.301.

47. Russel T Woodburne (1957) Essentials of Human Anatomy 2nd edition P – 376.

48. Sanudo J,Roig M,Rodriguez A,Ferreira B and Domenech J M(1993) Rare origin of the obturator, inferior epigastric and medial circumflex femoral arteries from a common trunk. J of Anatomy 1993,Vol 183, P – 161 -163

49. Sir Henry Morris (1893) Human Anatomy – Eleventh edition P –725

50. Sir John Bruce,Robert Walmsley,James A Ross (1964) Manual of Surgical Anatomy P – 294

51. Sir Solly Zuckerman (1961) A new system of Anatomy P -283

52. Suppa-ut Pungpapong,Sathon Thum-Umnauysuk(2005) Incidence of corona mortis;Preperitoneal Anatomy for Laparoscopic Hernia Repair. J Med Assoc.Thai2005;88(Suppl4):851-3

53. TeLinde Richard W (1894) TeLinde's Operative Gynaecology –Ninth edition P –99

54. Thomas Dwght (1907) Human Anatomy –Eighth edition P -820, 821.

55. Wahba, A. K.Offerdal, S.von Sommoggy and DE Birnbaum (1994) The morphology of the inferior epigastric artery has implications on its use as a conduit for myocardial revascularization, Eur J Cardiothorac Surg 1994;8:236-239.

56. Watanabe G,Misaki T,Yamamoto K,Cremer J,Haverich A,Borst H G,WatanabeY(1994) Use of inferior epigastric artery for coronary artery bypass grafting Kyobu Geka 1994 Feb 47(2):89-93 discussion 94-7.

LEGEND

IEA - Inferior epigastric artery
ITA – Internal thoracic artery
SEA –Superior epigastric artery
EIA – External iliac artery
EIV – External iliac vein
AOA – Abnormal obturator artery
IL – Inguinal ligament
LL – Lacunar ligament
RAM – Rectus abdominis muscle
PYR – Pyramidalis muscle
CrBr – Cremasteric branch
PuBr – Pubic branch
LatBr – Lateral branch
MedBr – Medial branch
UmbBr – Umbilical branch
MusBr – Muscular branch
TerBr – Terminal branch
SPC – Spermatic cord
UMB – Umbilicus
UMB Cord – Umbilical cord
PS – Pubic Symphysis
Mid – Midway between umbilicus and pubic symphysis
FR – Femoral ring
OF – Obturator foramen
ARC LINE – Arcuate line
U 1/3 – Upper 1/3 of rectus muscle
M 1/3 – Middle 1/3 of rectus muscle
L 1/3 – Lower 1/3 of rectus muscle
St I – Stem I
St II – Stem II
DIR – Deep inguinal ring
FA – Femoral ring
TI – Tunica intima
TM – Tunica media
TA – Tunica adventitia

STAINING PROCEDURE FOR FORMALIN FIXED SPECIMENS

Dehydration with graded alcohol

↓

Clearing with xylol

↓

Impregnation with wax

↓

Embedding

↓

Sectioning

↓

Mounting of Sections

↓

Staining

Staining

↓

Deparaffinization

↓

Hydration with graded alcohol

↓

Haematoxylin and Eosin Staining

↓

Dehydration

↓

Clearing

↓

Mounting the slide with DPX

(Cytoplasm – Pink)
(Nucleus – Purple)

Table No.1

Origin of the inferior epigastric artery in relation to the inguinal ligament

Specimen	Right	Left	Specimen	Right	Left
1	at	at	14	at	at
2	at	at	15	at	at
3	at	at	16	above	above
4	at	at	17	at	at
5	at	at	18	above	above
6	above	above	19	above	above
7	above	above	20	at	at
8	at	at	21	above	above
9	above	above	22	above	above
10	above	above	23	above	above
11	above	above	24	at	at
12	at	above	25	above	above
13	above	above			

at–at the level of inguinal ligament, above–above the level of inguinal ligament

CHART-1

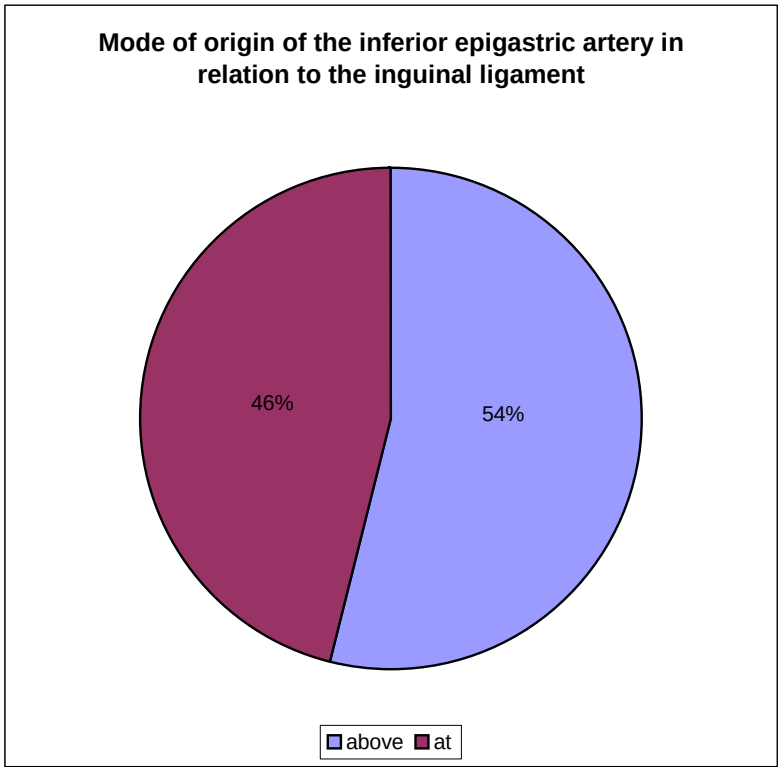

Table No.2

Distance of the origin of the inferior epigastric arteries above the inguinal ligament

Specimen	Distance (cm)	Specimen	Distance (cm)
6R	1	16L	1
6L	1	18R	0.5
7R	1	18L	0.5
7L	1	19R	1
9R	2	19L	1
9L	1.5	21R	1
10R	1	21L	1
10L	1	22R	1.3
11R	1.4	22L	1.3
11L	1.4	23R	1.5
12L	1.5	23L	1.5
13R	1.3	25R	0.5
13L	1	25L	0.5
16R	1		

Average=1.1cm

Table No.3

Level of entry of the inferior epigastric artery into the rectus muscle

Specimen	Right	Left	Specimen	Right	Left
1	M	L	14	M	L
2	L	M	15	L	M
3	U	M	16	M	M
4	M	L	17	M	L
5	L	U	18	L	L
6	M	M	19	M	M
7	M	M	20	L	L
8	M	M	21	M	M
9	M	M	22	U	U
10	M	M	23	U	M
11	M	M	24	M	M
12	M	M	25	M	M
13	M	M			

L –Lower Third
M –Middle Third
U –Upper Third

CHART-2

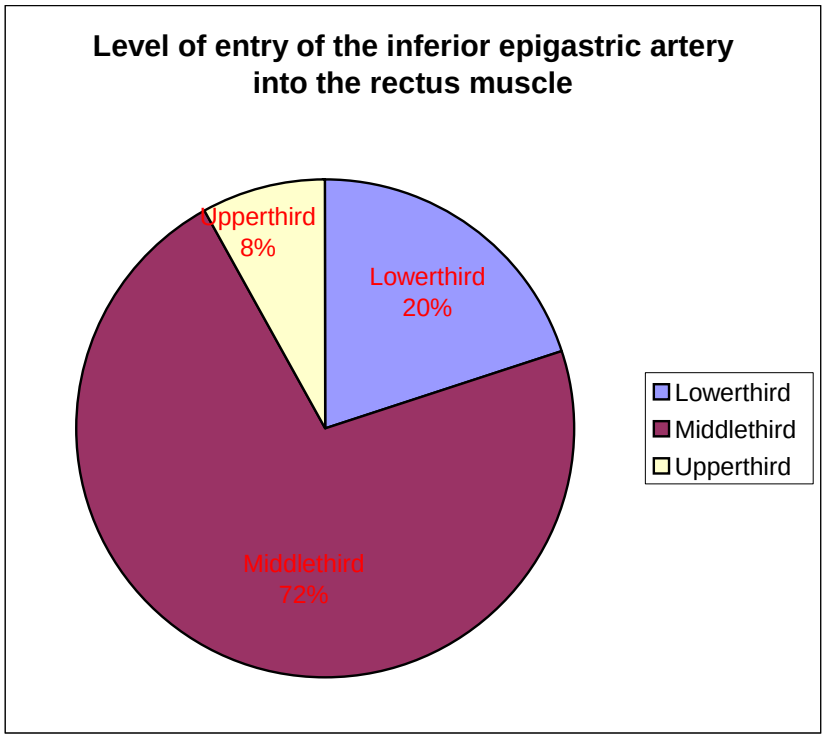

CHART-3

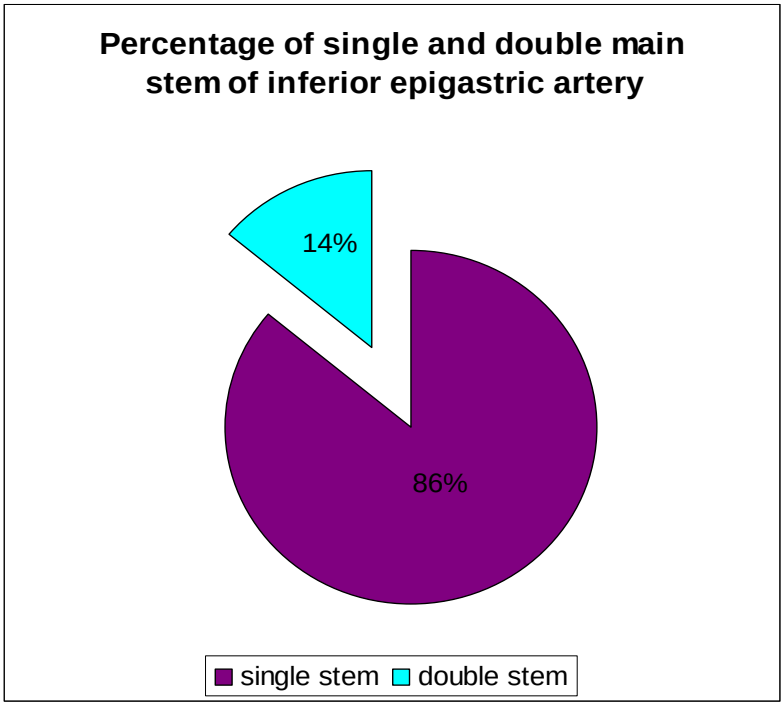

CHART-4

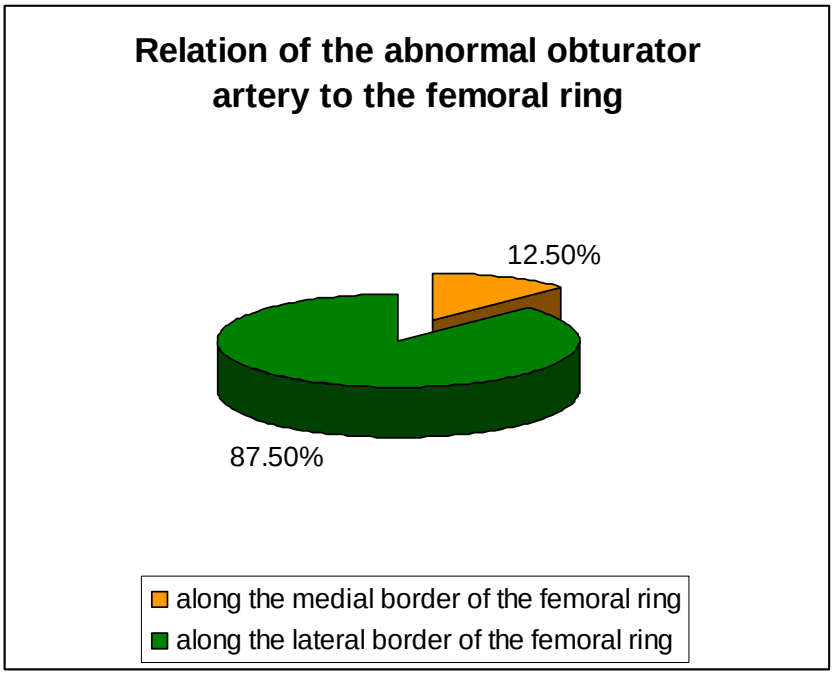

Table No.4

Pattern of anastomoses of the inferior epigastric artery with the superior epigastric artery

No anastomoses	**72%**
1 Anastomosis	16%
2 Anastomoses	10%
Multiple Anastomoses	2%

Table No.5

Distance of the inferior epigastric artery (cm) from the midline at the level of the umbilicus

Specimen	**Right**	**Left**	**Specimen**	**Right**	**Left**
1	3.1	3.2	14	3.9	3.8
2	3.4	3.0	15	4.0	3.3
3	3.1	3.1	16	3.3	3.4
4	3.2	3.5	17	3.6	3.5
5	3.6	3.5	18	3.5	3.1
6	3.5	3.0	19	3.1	3.9
7	3.1	3.1	20	3.7	4.0
8	3.2	3.3	21	3.7	4.1
9	3.8	3.4	22	4.1	3.8
10	4.0	3.4	23	4.2	3.3
11	3.1	3.7	24	3.6	3.1
12	3.2	3.9	25	3.5	3.0
13	3.4	3.6			

R- Right
Mean = 3.6 cm
Mean ± SD = 3.6 ± 0.2 cm

L-Left
Mean = 3.5 cm
Mean ± SD = 3.5 ± 0.2 cm

Table No.6

Distance of the inferior epigastric artery from the midline at the level midway between the umbilicus and the pubic symphysis

Specimen	Right	Left	Specimen	Right	Left
1	3.6	3.3	14	3.4	3.2
2	3.6	3.4	15	3.7	3.9
3	3.9	3.6	16	3.4	3.8
4	3.4	3.6	17	3.6	3.7
5	3.6	3.4	18	3.9	3.8
6	3.6	3.2	19	4.0	3.9
7	3.7	3.3	20	3.6	3.7
8	3.9	3.5	21	4.0	3.2
9	3.4	3.6	22	3.4	4.0
10	3.4	3.3	23	3.6	3.6
11	3.6	3.4	24	3.6	3.7
12	3.7	3.6	25	3.4	4.0
13	3.6	3.3			

R-Right
Mean = 3.5 cm
Mean ± SD =3.5 ± 0.4 cm

L-Left
Mean = 3.4 cm
Mean ± SD = 3.4 ± 0.3 cm

.

Table No.7

Distance of the inferior epigastric artery from the midline at the level just above the pubic symphysis

Specimen	Distance (cm)	Specimen	Distance (cm)
1R	3.9	1L	4.0
2R	4.0	2L	4.2
3R	6.2	3L	5.6
4R	5.9	4L	5.7
5R	4.5	5L	6.7
6R	5.7	6L	3.8
7R	6.3	7L	7.3
8R	3.5	8L	6.9
9R	6.2	9L	7.4
10R	7.5	10L	6.3
11R	3.5	11L	3.8
12R	6.5	12L	5.3
13R	7.8	13L	4.9
14R	6.8	14L	8.0
15R	7.6	15L	6.3
16R	5.3	16L	6.7
17R	7.8	17L	7.8
18R	6.4	18R	7.4
19R	5.4	19L	6.8
20R	7.8	20L	3.8
21R	6.3	21L	8.0
22R	6.2	22L	7.3
23R	3.6	23L	6.8
24R	4.5	24L	7.2
25R	5.0	25L	7.3

R-Right
Mean = 5.7 cm
Mean ± SD = 5.7±1.1 cm

L-Left
Mean =6.2 cm
Mean ± SD = 6.2 ± 1.3 cm

Table No.8

Distance from the insertion of the rectus tendon to the intersection of the inferior epigastric artery with the lateral rectus margin

Specimen	Distance (cm)	Specimen	Distance (cm)
1R	4.0	1L	5.0
2R	5.3	2L	6.3
3R	6.2	3L	4.4
4R	4.3	4L	5.4
5R	4.2	5L	6.8
6R	3.4	6L	5.1
7R	5.4	7L	6.1
8R	5.1	8L	4.8
9R	4.3	9L	4.3
10R	3.5	10L	4.1
11R	4.6	11L	5.2
12R	6.4	12L	6.2
13R	3.5	13L	6.1
14R	4.5	14L	6.0
15R	4.3	15L	5.2
16R	4.0	16L	5.1
17R	3.6	17L	6.7
18R	3.4	18L	7.0
19R	4.6	19L	6.3
20R	6.7	20L	4.3
21R	5.3	21L	7.0
22R	6.2	22L	5.4
23R	5.2	23L	4.7
24R	4.2	24L	4.8
25R	4.0	25L	5.6

R-Right L-Left

Mean = 5 cm

Mean ± SD = 5 ± 1.2 cm

Table No.9

Length of the inferior epigastric artery from its point of origin to its entrance into the rectus sheath

Specimen	Length (cm)	Specimen	Length (cm)
1R	4.2	1L	5.3
2R	5.0	2L	5.6
3R	4.6	3L	6.2
4R	5.2	4L	7.3
5R	3.0	5L	7.0
6R	5.7	6L	6.0
7R	5.3	7L	4.8
8R	6.2	8L	4.6
9R	4.8	9L	5.0
10R	5.6	10L	6.6
11R	5.5	11L	7.0
12R	4.6	12L	4.3
13R	6.8	13L	5.8
14R	4.5	14L	6.2
15R	5.8	15L	5.2
16R	5.6	16L	6.3
17R	6.5	17L	7.2
18R	6.9	18L	6.9
19R	5.8	19L	7.1
20R	4.9	20L	7.4
21R	7.2	21L	5.8
22R	5.7	22L	6.3
23R	6.8	23L	7.0
24R	5.0	24L	6.8
25R	4.2	25L	5.9

R-Right L-Left

Mean Length =5.8 cm

Mean ± SD =5.8 ± 0.9 cm

Table No.10

Length of the inferior epigastric artery from its point of origin to its entrance into the rectus muscle substance

Specimen	Length (cm)	Specimen	Length (cm)
1R	7.2	1L	10.8
2R	9.4	2L	12.4
3R	10.6	3L	13.6
4R	8.6	4L	9.4
5R	9.7	5L	4.3
6R	10.9	6L	8.6
7R	8.4	7L	6.9
8R	4.0	8L	7.3
8R	9.2	9L	8.4
10R	6.8	10L	6.8
11R	7.4	11L	13.2
12R	9.6	12L	12.9
13R	12.4	13L	8.6
14R	13.6	14L	12.4
15R	14.8	15L	11.4
16R	12.6	16L	9.2
17R	8.8	17L	11.4
18R	9.7	18L	14.0
19R	11.4	19L	12.4
20R	12.6	20L	10.6
21R	15.0	21L	10.5
22R	11.5	22L	13.0
23R	10.6	23L	12.8
24R	12.5	24L	7.4
25R	15.4	25L	9.2

R-Right L-Left

Mean Length = 10.4 cm

Mean ± SD =10.4 ± 2.6 cm

Table No.11

(a) Diameter of the inferior epigastric artery at its origin

Image	Diameter (mm)
1	2.9
2	2.8
3	2.8
4	2.7
5	2.6
6	2.6
7	2.6
8	2.6
9	2.9
10	3.0
11	2.0
12	3.1
13	3.2
14	2.7
15	2.7
16	2.8
17	2.6
18	2.6
19	2.6
20	2.8

Mean Diameter = 2.8 mm

Mean ± SD = 2.8 ± 0.2 mm

Table No.12

(b)Diameter of the inferior epigastric artery at its entrance into the rectus muscle

Image	Diameter (mm)
1	2.1
2	2.3
3	2.2
4	2.1
5	2.0
6	2.6
7	1.8
8	1.8
9	1.9
11	2.0
12	2.3
13	2.2
14	2.1
15	1.7
16	1.8,1.9
17	1.8
18	1.8
19	1.9
20	1.9

Mean Diameter = 2 mm

Mean ± SD = 2 ± 0.1 mm

Table No.1D

Distance of inferior epigastric artery from the midline at 3 levels

Level	Distance (Mean ± S.D)			
	Alan A Saber study (2004)		Present study (2009)	
	Right	Left	Right	Left
Umbilicus	5.88 ± 0.14	5.55 ± 0.13	3.5 ± 0.4	3.4 ± 0.3
Midway	5.32 ± 0.12	5.25 ± 0.11	3.6 ± 0.2	3.5 ± 0.2
Pubic symphysis	7.47 ± 0.10	7.49 ± 0.09	5.7 ± 1.1	6.2 ± 1.3

Midway – Midway between Umbilicus and Pubic symphysis